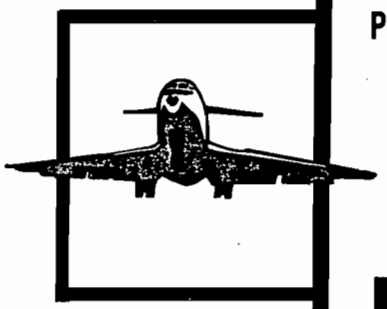

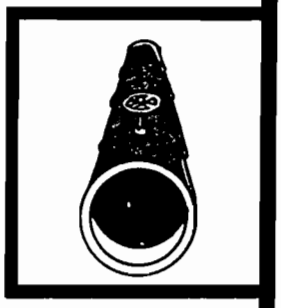

PB86-917006

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

SAFETY STUDY

PERFORMANCE OF LAP BELTS IN 26 FRONTAL CRASHES

NTSB/SS-86/03

UNITED STATES GOVERNMENT

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. NTSB/SS-86/03	2. Government Accession No. PB86-917006	3. Recipient's Catalog No.
4. Title and Subtitle Safety Study—Performance of Lap Belts in 26 Frontal Crashes		5. Report Date July 28, 1986
		6. Performing Organization Code
7. Author(s)		8. Performing Organization Report No.
9. Performing Organization Name and Address National Transportation Safety Board Bureau of Accident Investigation Washington, D.C. 20594		10. Work Unit No. 4378A 11. Contract or Grant No.
12. Sponsoring Agency Name and Address NATIONAL TRANSPORTATION SAFETY BOARD Washington, D. C. 20594		13. Type of Report and Period Covered Safety Study 1984-1986 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract This study reports on the performance of lap belts in 26 frontal crashes of passenger vehicles investigated by the Safety Board. The report discusses the Board's findings, selected lap belt cases, statistical estimates of seat belt effectiveness, related research on lap belt performance, and Federal regulations and manufacturers' practices on motor vehicle seat belts. The report concludes with recommendations to U.S. and foreign manufacturers of passenger vehicles, to the National Highway Traffic Safety Administration, to the International Chiefs of Police, and to associations and groups concerned with emergency medicine.

17. Key Words	18. Distribution Statement
lap belt; lap/shoulder belt; seat belt; restraint systems; injury; medical treatment; motor vehicle;	This document is available to the public through the National Technical Information Service Springfield, Virginia 22161

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	236	

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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

SAFETY STUDY

Adopted: July 28, 1986

PERFORMANCE OF LAP BELTS IN 26 FRONTAL CRASHES

INTRODUCTION

For many years, the National Transportation Safety Board has supported efforts to increase the use of seat belts to protect motorists from severe injury or death in crashes. More recently, however, the Safety Board has felt that it would be useful to undertake a special crash investigation program focused on accidents involving the use of seat belts to learn more about their performance. This view was based on a number of facts. First, the manual belt systems in motor vehicles today are not required to be dynamically tested for crash protection performance (those requirements are limited to passive systems, such as passive belts or airbags). Second, data on real-world performance of belt systems are limited. Furthermore, there have been basic changes in vehicle designs over the years that could affect the performance of belt systems designed for vehicles of the 1970's. For example, there was concern that, with the "downsizing" of automobiles, the ability of seat belts to provide crash protection might be diminished. In vehicles with less distance between front seat occupants and frontal interior surfaces, for instance, such problems as excessive spool-out of the upper torso restraint in lap/shoulder belts might permit injurious contact between the occupant and the interior surfaces, despite use of the belt.

Therefore, in the fall of 1984, the Safety Board embarked on a program to investigate approximately 200 crashes in which the crash performance of seat belts would be thoroughly examined. The criteria for investigating a crash were:

-- Case vehicle must be post-1974 model car, light truck, or van;

-- At least one occupant in the case vehicle must have been using a seat belt 1/;

-- The crash must have been of sufficient severity to require that the case vehicle be towed from the scene 2/; and

-- The crash must not have been so severe for the case vehicle as to be deemed unsurvivable for its belted occupant(s). 3/

1/ Before the program was completed, it was decided to investigate a few cases in which no occupants were restrained, for comparison purposes.
2/ As the program progressed, it was found that, for a wide variety of reasons, vehicles may be towed even though they are essentially undamaged. Since in these cases the "crash" was extremely minor and seat belts could not be expected to affect the outcome, these particular towaway cases were not followed up.
3/ That is, there must have been sufficient space after the crash at the seating locations of the belted occupants to permit survival.

The Safety Board's investigators were alerted to potential cases for the study in a number of ways. The Board's highway field investigators, trained in the techniques of investigating crashes involving restrained occupants, are located in eight cities: Atlanta, Chicago, Denver, Fort Worth, Kansas City (Missouri), Los Angeles, New York, and Seattle. At the beginning of the program, each of these field offices arranged an accident notification scheme, involving a network of law enforcement and medical authorities in the multistate region surrounding the Board field office. These authorities agreed to notify the Board investigators of any crash meeting the Board's criteria as soon as they became aware of it. Upon notification, Board investigators would go to the accident location, explore the facts sufficiently to determine that the crash in fact met the selection criteria, and if so, begin a detailed examination to establish all the relevant facts.

A careful examination of the case vehicle was carried out in each crash investigation, documenting its "vital statistics" and information about the restraint system available to each occupant. The size, weight, and seating location of each occupant was determined. For each occupant, the investigator determined whether the available seat belt was used, whether it was used correctly, the nature and severity of each injury sustained (expressed in terms of the Abbreviated Injury Scale (AIS)), and the probable source of each injury. Necessary measurements were made that permitted the Safety Board to estimate the collision severity in terms of the velocity change ("Delta V") experienced by the case vehicle. Based on these data, an analysis could be made of the performance of each belt system in use during the crash, and some overall conclusions drawn about the role of belt restraint systems in the crashes studied.

After about a quarter of the investigations had been initiated, several cases involving lap belted rear seat occupants began to draw the Safety Board's attention to these belt systems in particular. For example, in one case involving a rather moderate collision (Delta V 25.7 mph), the lap/shoulder belted front seat occupants sustained no injuries, while the lap belted left rear seat occupant sustained three critical intra-abdominal injuries, two severe intra-abdominal injuries, five serious intra-abdominal injuries, one serious hip injury, one moderate intra-abdominal injury, and three moderate hip injuries--all induced by the lap belt itself. This man died after 39 hours in the intensive care unit.

Despite the concern about the apparent poor performance of the lap-only belt in several early cases, the accident notification criteria were not changed. However, after several more cases turned up involving rear seat lap belts, it was decided to alert the field investigators to look especially carefully at potential cases involving occupants restrained in the rear seat (as distinct from the earlier, more general criterion of "at least one occupant in the vehicle using a seat belt").

In all, the Safety Board was notified of 26 accident cases involving lap belt restrained occupants that also met the other notification criteria established for the program. This report presents findings on the performance of the seat belts used in these 26 cases--50 lap-only belts, 32 lap/shoulder belts--and on the experience of the 57 unrestrained occupants in these cases and in 3 other cases involving only unrestrained occupants, studied for comparison purposes. In addition, one case involving front and rear seat occupants, all using lap/shoulder belts, was studied, again for purposes of comparison.

It is important to remember that this study is limited in two important respects. First, the crashes examined here (with one exception) are all frontal crashes. Results derived from analysis of frontal collisions cannot be applied to other crash configurations.

The benefits that may be derived from lap belt use (compared to no restraint) in minimizing the possibility of ejection during rollover or side impact cannot be discovered through analyzing frontal collisions. Second, the small size of the sample in this study means that no statistically valid conclusions can be drawn from it. The Safety Board's study is a case study which emphasizes the collection of accurate, complete data on a number of specific points relevant to the question of belt performance.

The report begins with an overview of the findings of the lap belt crash investigation program. This overview is followed by brief summaries of several illustrative cases and discussion of their significance. The next section discusses the reasons why large-scale databases have been inappropriate for assessing seat belt effectiveness. A chapter describing what has been known about lap belts and lap/shoulder belts since their use began in the 1960's is next, including knowledge of the special problems in diagnosing and treating lap belt injured persons. The relationship of the Federal Motor Vehicle Safety Standards to lap belt and lap/shoulder belt installation is covered in the next section. The final section presents several recommendations for improving occupant restraint systems and recommendations for improving the handling of persons injured in motor vehicle crashes while wearing a seat belt.

Several appendices follow the report, the first being a presentation, in brief format, of all the study cases, describing the facts of each case and discussing the Safety Board's interpretation of these facts. Other appendices present additional cases from other sources of lap belt injured persons; a glossary; discussions of "Delta V" and the use of the AIS; anatomical drawings to assist in understanding the nature of the injuries described in this report; a chronology of selected events related to seat belts since their early development; and a number of tables depicting various findings from the Board's lap belt case investigations.

OVERVIEW OF FINDINGS FROM SAFETY BOARD CRASH INVESTIGATIONS

The Safety Board investigated 26 crashes involving at least one lap belted person and concluded that, overall, the crash performance of the lap belts in these cases was very poor. Among the 50 persons using a lap-only belt, the Board determined that at least 32 of them would have fared substantially better if they had been wearing a lap/shoulder belt. In many cases, the lap belts induced severe to fatal injuries that probably would not have occurred if the lap belts had not been worn. The occurrence of lap belt induced severe to fatal injuries was not limited to severe crashes: 14 lap belted occupants sustained belt induced injuries of AIS 3 or greater severity (including 6 fatally injured) in crashes of Delta V 28 mph or lower. Even correctly 4/ worn lap belts induced severe injury: 24 occupants who received AIS 3 or greater injuries from the belt itself are believed to have been wearing it correctly. Twenty-six of the lap belted occupants sustained serious to fatal injuries in crashes in which other occupants--either unrestrained or lap/shoulder belted, and often seated in the more vulnerable front seating locations--were less seriously injured or not injured at all. The injuries characteristically induced by the lap belt were among the most dangerous types of injuries: those to the head, spine, 5/ and abdomen. The ages of lap belt injured persons ranged from 4 to

4/ There is no officially agreed-upon definition of "correct" lap belt use, but the Safety Board has used the term to mean snugly crossing the lower abdomen between the pubis and the umbilicus, with the belt low on the hips below the crest of the ilium. This appears to be the generally accepted meaning.

5/ In this study, lap belt induced head and spine injuries are those brought about by the violent jackknifing motion over the lap belt—injuries that would not have occurred but for the use of the lap belt.

82 years (more than half were younger than 15 years, however) and included both males and females. Finally, the postcrash medical handling of several of the lap belt injury victims demonstrated the need for improved understanding by medical personnel of the possibility and gravity of seat belt induced injuries in motor vehicle crashes.

Injuries to Case Vehicle Occupants

Thirty-one vehicles (passenger cars or vans), occupied by 139 persons ranging in age from 10 months to 82 years, were involved in this lap belt study. 6/ The crash forces involved in these primarily frontal crashes ranged from Delta V 9.8 mph to Delta V 43 mph. Fifty-seven of the occupants were unrestrained, 27 of them in a front seat location, 30 in some other seating location. Thirty-two were wearing a lap/shoulder belt, all but 1 in a front seat. Fifty were wearing a lap belt, all but 3 in a rear seating location.

Only 7 of the 139 occupants were uninjured. Five of them were in crashes of low Delta V (10-13 mph)--4 of them unrestrained, 1 lap belted, all in the rear seat. The other 2 were in the front seat wearing lap/shoulder belts in a moderately severe crash (Delta V 25 mph).

Another 48 occupants received AIS 1 (minor) injuries as their most severe injury (MAIS); 32 received AIS 2 (moderate) injuries as most severe; 21 received AIS 3 (serious) injuries as most severe; 31 received AIS 4 (severe), AIS 5 (critical), or AIS 6 (maximum) injuries. Eighteen persons died of their crash induced injuries: 1 with AIS 2 injuries, 1 with AIS 3, 1 with AIS 4, 11 with AIS 5, and 4 with AIS 6.

	Uninjured	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	MAIS 6	(Fatal)
Unrestrained (57)	4	20	17	11	1	2	2	(4)
Lap belted (50)	1	16	5	7	6	13	2	(13)
Lap/shoulder belted (32)	2	12	10	3	4	1	-	(1)

Restraint Use, Injuries, Delta V

AIS 2 As Most Severe Injury (MAIS 2). Of the 139 occupants, 32 received MAIS 2 (moderate) injuries; 17 of them were not restrained, 5 were wearing lap belts, and 10 were wearing lap/shoulder belts.

Persons With MAIS 2 Injury,
by Case Vehicle Delta V and Restraint Use

	<15 mph	15-25 mph	26-35 mph	36-45 mph
Unrestrained (17)	-	4	2	11
Lap belted (5)	-	3	1	1
Lap/shoulder belted (10)	1	3	4	2

6/ A 5-month-old boy, using an improperly installed child restraint device, sustained AIS 3 head injuries in a crash of Delta V 33.6 mph; this occupant will not be included in the discussion and tables that follow.

Most of the unrestrained persons at the moderate injury level were in severe crashes (11 of the 17 in crashes of Delta V greater than 35 mph); the lowest case vehicle Delta V for these occupants was 23 mph. There were only 5 lap belted persons at the moderate injury level; 1 was in a crash at Delta V 38.5 mph, 1 at Delta V 35.7 mph, and 3 at Delta V 15-25 mph. The lap/shoulder belted persons with moderate injuries were in moderate to severe crashes (6 of 10 in crashes at Delta V 26-45 mph).

AIS 3 As Most Severe Injury (MAIS 3). Of the 139 occupants, 21 received MAIS 3 (serious) injuries; 11 of them were not restrained, 7 were wearing lap belts, and 3 were wearing lap/shoulder belts.

Persons With MAIS 3 Injury,
by Case Vehicle Delta V and Restraint Use

	<15 mph	15-25 mph	26-35 mph	36-45 mph
Unrestrained (11)	-	1	4	6
Lap belted (7)	-	1	6	-
Lap/shoulder belted (3)	-	1	2	-

Most of the unrestrained persons with MAIS 3 injuries were in severe to very severe crashes (6 of 11 at Delta V greater than 35 mph, 3 more at Delta V 33-35.5 mph). Most of the lap belted persons with MAIS 3 injuries were in moderately severe crashes (6 of 7 at Delta V less than 35 mph, 4 of these at Delta V less than 30 mph). All three lap/shoulder belted persons with MAIS 3 injuries were in moderately severe or severe crashes (Delta V 33.6 mph, 32 mph, and 22.5 mph).

MAIS 4, 5, or 6, or Fatal Injuries. Of the 139 occupants, 33 received MAIS 4, 5, or 6 injuries, or were killed. Only 5 of these occupants were not restrained; 5 of them were wearing lap/shoulder belts. The remainder, 23 of the 33, were wearing lap belts.

Of the 33 occupants in this category, 18 were killed; 4 of them were not restrained and were in higher Delta V collisions (43 mph and 35.5 mph); 1 was wearing a lap/shoulder belt (a driver in a Delta V 36 mph crash); 13 were wearing lap-only belts (6 at Delta V less than 30 mph, 7 at Delta V 30-40 mph).

Persons With MAIS 4, 5, or 6 Injuries or Killed, 7/
by Case Vehicle Delta V and Restraint Use

	<15 mph	15-25 mph	26-35 mph	36-45 mph
Unrestrained (5)	-	-	1	4
Lap belted (23)	-	5	12	6
Lap/shoulder belted (5)	-	-	3	2

Only 5 of the 57 unrestrained persons sustained these level injuries; 4 were in vehicles that underwent Delta V of greater than 35 mph; 1 was in a crash of Delta V 25-28 mph. Four of the 5 were in a front seat in these severe frontal collisions.

7/ Of the 31 persons who sustained MAIS 4, 5, or 6 injuries, 16 were killed. In addition, 2 other persons were killed, 1 with MAIS 2 injuries, and 1 with MAIS 3 injuries.

The 5 lap/shoulder belted persons who suffered these levels of injuries also were involved in severe crashes (3 at Delta V 32 mph, 1 at Delta V 36 mph, and 1 at Delta V 38.5 mph). Four of the 5 were drivers.

There were 23 lap belted persons in this category. Six were in crashes involving Delta V 36-40 mph, 12 were in crashes of Delta V 26-35 mph, and 5 were in crashes of Delta V 20-25 mph. One of the 23 persons was a driver, 1 was seated center front, and 2 were seated right front. The remaining 19 were all seated in rear locations.

Thirteen of the 23 lap belted persons in this category were killed, all by lap belt induced injuries. Five more sustained MAIS 4 injuries but were not killed, and another 5 sustained MAIS 5 injuries but were not killed.

Sixteen of the 23 lap belted persons who sustained MAIS 4, 5, or 6 injuries or were killed were judged to have been wearing the belt correctly and also did not slide downward under the belt or have the belt slide up over the iliac crests ("submarining"). Four were judged to have been wearing the belt correctly but possibly to have submarined. One was judged to have been wearing the belt incorrectly (loose or too high).

Twenty-one of the 23 lap belted persons in this category were in vehicles in which at least one other person, unrestrained or lap/shoulder belted, was either uninjured or had MAIS 1, 2, or 3 level injuries. In all but one of these cases, there was more than one non-lap belted person who survived the crash with less than AIS 3 injuries, often in a front seat position.

Seven of the 23 lap belted persons in this category were younger than 10 years; 8 were aged 10-20; 4 were aged 21-50; 4 were older than 51. Fifteen were male, 8 were female.

Additional Information on Persons Wearing Lap-Only Belts

The Safety Board's investigators concluded that 35 of the 50 lap belted occupants were wearing the belt correctly and also did not submarine. Five other lap belt wearers were judged to have been wearing the belt correctly but to have experienced, or possibly experienced, submarining. Seven of the lap belt wearers were judged to have worn the belt incorrectly or probably incorrectly. For three of the lap belt wearers, there was insufficient evidence to determine whether it was being worn correctly and whether it rode up during the impact.

Correct/Incorrect Use, Submarining

Wore lap belt correctly, no submarining	37
Wore lap belt correctly, but possible submarining	4
Wore lap belt incorrectly	5
Correctness of use and occurrence of submarining unknown	4

Of the 50 persons wearing a lap belt in these crashes, 49 were injured:

Outcomes for 50 Lap Belt Users

Survivors	MAIS 1:	16
	MAIS 2:	4
	MAIS 3:	6
	MAIS 4:	5
	MAIS 5:	5
Killed		13

There was little or no intrusion or compression of the occupant space in the areas surrounding the 13 fatally injured lap belt wearers. They all received their fatal injuries as a result of wearing the lap belt. Eleven of these 13 were wearing the lap belt correctly; there was possible submarining in 3 of the 13 lap belt induced fatalities, all involving proper use of the belt.

Of the 33 lap belted persons who received AIS 2 or greater injuries, 30 received one or more of these injuries as a direct result of the lap belt. One other person received an intra-abdominal injury as a result of lap belt use, but its severity was undocumented.

Of the 29 persons with AIS 3 or greater (or fatal) lap belt induced injuries, 21 sustained more than one injury at this level (induced by the lap belt itself):

Distribution of AIS 3 or Greater Lap Belt Induced Injuries

Persons with 2 such injuries:	4
Persons with 3 such injuries:	3
Persons with 4 such injuries:	4
Persons with 5 such injuries:	5
Persons with 6 such injuries:	1
Persons with 7 such injuries:	1
Persons with 10 such injuries:	3

SELECTED LAP BELT CASES

Detailed factual and analytical summaries of each case in this study are presented in appendix A. Several cases are presented here to illustrate many of the findings set out in the previous section.

In Case 1, a 15-year-old female driver lost control of the 1983 Pontiac Phoenix she was driving and crashed head-on into a tree. The Delta V was calculated to be 37 mph. The girl driving and the 12-year-old boy in the right front seat sustained only minor to moderate injuries, despite the fact that they were not using the available lap/shoulder belts and despite the fact that they were in the most vulnerable seating location for a frontal collision. The two 13-year-old boys wearing lap belts in the rear seat, however, both sustained violent injuries to the intra-abdominal organs and connecting tissue; one boy was pronounced dead less than 1 hour after the crash, and the other boy died 5 days later (he had shown no brain activity from the time of the crash). The Safety Board concluded that both boys probably were wearing the lap belt in the proper pelvic area, though it is possible that one boy's belt "rode up" over the iliac crests during the crash.

In Case 4, a 1983 Dodge 15-passenger van was struck by a 1970 Chevrolet Chevelle, with the van undergoing an estimated Delta V 38.5 mph. The van driver, a 36-year-old man, was using his 3-point lap/shoulder belt; however, since he was seated directly behind the area of major crash induced vehicle collapse, he sustained moderate to severe injuries, primarily to his head, face, and legs. The unrestrained right front passenger, a 17-year-old boy, sustained only minor injuries. Eight other unrestrained young people sustained only minor or moderate injuries; all were treated and released the same day.

The remaining four young men in the van were wearing lap belts. One sustained serious lap belt induced injuries to the head, spine, and iliac crest and severe lap belt induced intra-abdominal injuries (in addition to numerous other minor to moderate lap belt induced injuries); he was hospitalized for an extended period and continued under out-patient care after hospitalization. When last contacted by the Safety Board, 7 months after the crash, he was still unable to work.

A second lap belted passenger received moderate, serious, and severe lap belt induced head injuries and spent 4 months in a hospital before being transferred to another facility for long-term care. Seven months after the crash, he was still under extended care and on full disability.

A third lap belted passenger received fractures of his left leg due to an unsecured spare tire under his seat moving forward and compressing his leg against the forward seat framework. His head struck the seatback in front of him, as those of the first two lap belted passengers did, but with reduced severity, probably due to the lesser rigidity of the seat framework immediately in front of him. He also received an injury to his urinary tract, probably lap belt induced, of unknown severity. He was in a hospital for a week, and could not return to work for 4 months.

The fourth lap belted passenger sustained critical and severe lap belt induced intra-abdominal injuries and serious lap belt induced spine injuries. He spent 2 months in a hospital and had to return for out-patient care once a month after that. Seven months after the accident he had not returned to work and was on disability.

In Case 6, a 1983 Chevrolet Malibu was struck in the front by a 1980 Ford Mustang, with a resulting Delta V for the Chevrolet of 23 mph. The lap/shoulder belted Chevrolet driver, a 58-year-old man, received only minor injuries; the unrestrained right front passenger, a 55-year-old woman, received a moderate level injury to her head, in the form of a 2-inch temple laceration when she struck the rearview mirror; her other injuries were minor. However, the lap belted rear seat passenger, a 56-year-old woman, received fatal lap belt induced intra-abdominal injuries and died within minutes of reaching the hospital.

In Case 23, 12 small children (aged 6-7 years) were being transported in a day care van. The Ford van struck a 1984 Lincoln Town Car, resulting in a Delta V of 25-28 mph for the van. The unrestrained 24-year-old woman driver of the van received severe injuries. The five unrestrained small child occupants received only minor injuries and were either treated and released or did not receive medical treatment at all. The seven children wearing lap belts, however, all received serious to critical injuries including head, pelvic, intra-abdominal, and spinal injuries, all induced by the lap belt. One of these children was killed due to her massive head, spine, and intra-abdominal injuries; the others spent considerable time in a hospital, two being transferred later to extended-care facilities.

In Case 24, six young men (21-25 years old) were crowded into a 1979 VW Rabbit when it struck a 1977 Chevrolet Impala. The VW underwent a Delta V of 35.5 mph, while the Chevrolet underwent a Delta V of 23 mph. The four unrestrained men in the Chevrolet, all aged 22, sustained only minor to moderate injuries; all were treated and released immediately. The unrestrained driver of the VW Rabbit sustained critical injuries and died instantly. The lap/shoulder belted right front passenger sustained only moderate injuries, as did two of the unrestrained rear seat passengers. A third unrestrained rear seat passenger, sitting on the lap of the man in the center position, sustained serious injuries, due to being compressed between the center occupant and front seat. The remaining rear seat occupant, wearing a lap belt, sustained critical lap belt induced head and intra-abdominal injuries, serious lap belt induced spinal injuries, and moderate lap belt induced injuries to the abdomen.

In Case 26, a 1985 Ford Escort struck a 1974 International Harvester tractor-trailer, with a resulting Delta V of 33.5 mph for the Ford. The most serious injury sustained by the unrestrained 16-year-old girl driving the Ford was a fractured left femur (AIS 3); the same was true for the unrestrained 15-year-old girl in the right front seat. A 14-year-old boy in the rear, wearing a lap belt, sustained severe to critical lap belt induced intra-abdominal injuries and died 5 hours later. An 11-year-old boy wearing a lap belt in the rear seat sustained 4 severe intra-abdominal injuries, 4 critical intra-abdominal injuries, 1 critical spinal injury, 1 serious abdominal injury, and 1 moderate abdominal injury (in addition to other minor lap belt induced injuries). All his moderate to critical injuries were lap belt induced. He spent 2 months in a hospital before being transferred to an extended-care facility, due to paraplegia from his spinal column injury.

In Case 27, a 1980 Dodge Colt struck a tree head-on, with a resulting Delta V of 28 mph for the Dodge. The lap/shoulder belted front seat occupants sustained only minor injuries; however, the lap belted 15-year-old boy in the rear seat sustained severe intra-abdominal and spinal injuries due to the lap belt.

These cases illustrate why the Safety Board is concerned about the poor performance of lap belts in many crashes. Although virtually all of the lap belted persons were seated in rear seats (less vulnerable in a frontal crash), they often sustained serious to fatal injuries while front seat occupants received lesser or no injuries. Often the lesser injured occupants were unrestrained, while the more seriously or even fatally injured were lap belted. The unrestrained or lap/shoulder belted occupants tended to sustain only AIS 1-3 level injuries, even in severe to very severe crashes (only 5 of the 57 unrestrained occupants sustained higher level injuries, although 43 of these occupants were in severe to very severe crashes; only 5 of the 32 lap/shoulder belted occupants sustained higher level injuries, although 15 of these occupants were in severe to very severe crashes). At the same time, the lap belted occupants tended to receive AIS 4, 5, 6, and fatal injuries (21 of the 50 lap belted occupants, 11 of whom died, received AIS 4-6 level injuries; 2 of the 28 lap belted occupants whose highest documented injury was AIS 1-3 also died). The majority (23 of 29) of seriously to fatally injured lap belt wearers were believed to have been using the lap belt correctly--snug and low on the hips.

It is also important to understand that even in the cases in which lap belted persons did not sustain serious belt induced injuries, the lack of injury could not be attributed to effective crash protection performance by the lap belt. In Case 5, for instance, a 14-year-old lap belted boy sustained only AIS 1 injuries. However, the Delta V involved in this crash was only 9.8 mph; three unrestrained persons sustained no injuries, and the highest injury among all six occupants was AIS 2 (the lap/shoulder belted driver). Significantly, it was found that the buckle of the lap belt did not hold at impact; either the buckle failed (the evidence was against this) or the boy had not latched it properly in

the first place (most likely). Thus, little or no restraint was provided by the lap belt in this low Delta V crash. In three other crashes (Cases 14, 15, and 16), the Delta V was quite low and no occupants (even unrestrained) sustained other than minor injuries.

In four crashes (Cases 8, 11, 12, and 21), the Delta V was moderate (around 20 mph). In one, a lap belted 5-year-old girl in the rear of a 1977 Chevette sustained only AIS 1 injuries. However, another 5-year-old girl seated next to her, of identical size and weight, was also lap belted; she sustained maximum level injuries (AIS 6) to her head and cervical spine, plus other injuries. She died of her lap belt induced head/spine injuries. The Safety Board concluded that the radical difference in these children's experiences was probably due to slight differences in the attitude of their heads as their upper bodies flexed violently downward--a matter of chance.

In Case 11, all four lap belted children received only AIS 1 level injuries. Two toddler boys were belted together in the front seat using the lap portion of a 3-point lap/shoulder belt; the Safety Board concluded that little restraint was provided by the belt, however, since much of the crash energy acting on them was dissipated by the contact between their bodies and their head strikes into the well-padded instrument panel. The outboard seated child also avoided belt induced abdominal bruising, the Board concluded, because he loaded the inboard seated child into the belt; that child received belt bruising on both the left and right sides. The lap belted 5-year-old girl in the left rear seat probably avoided more serious lap belt injuries because she flexed over the belt in a leftward direction, thus bringing her upper body and head down onto her left upper leg; this prevented the serious head and neck injuries sustained by children wearing lap belts who flex downward between the legs. The same was true for the lap belted 4-year-old girl in the right rear seat.

In Case 12, a woman was lap belted in the left rear seat position. She sustained three moderate (AIS 2) injuries to her head and face, resulting from violent jackknifing induced by the lap belt, and an AIS 2 hip injury (plus several other injuries). She sustained the most serious injuries of the three occupants.

In the final example of a quite moderate crash, Case 21, the two lap belted rear seat occupants sustained only minor injuries. The Safety Board concluded that they had decelerated mainly into the front seatback, not into the lap belt. The two lap/shoulder belted front seat occupants also sustained only minor injuries.

There were three cases involving moderately severe to severe crashes in which lap belted occupants sustained only minor to moderate injuries. However, even in these cases the Safety Board concluded that this was not due to safe and effective restraint provided by the lap belt. In Case 3, the lap belted 6-year-old boy in the center rear seat of the 1984 Chevrolet Impala involved in a head-on crash at Delta V 28.6 mph sustained only minor injuries. However, the Board found that 1) the lap belt was not in fact "snugged up" around him at the time of the crash; 2) when his body slid forward and finally made contact with the belt webbing, the latchplate did not lock the webbing in place but allowed it to slip through for several inches before it finally jammed on a folded-over section; and 3) a large plastic box on the boy's lap was shattered between the boy and the front seatback, thus accounting for much of the boy's deceleration. Thus, this boy was not restrained to any significant degree by the lap belt.

In Case 7, a 1983 Chevrolet Celebrity was involved in a severe crash (Delta V 38 mph). The most severe injury sustained by the lap belted left rear seat occupant was AIS 2. However, the Safety Board investigation showed that he decelerated primarily into the left interior side wall and B pillar, not into the lap belt, so that his lack of lap belt induced internal or spinal injuries is not surprising. The belt was not effective in preventing head injuries; he sustained five AIS 2 injuries to his head and face, necessitating more than 8 weeks in a hospital and 2 months' loss of work.

Finally, in Case 13, three children were lap belted: one at center front seat, two in the rear seat. The child at center front sustained AIS 2, 3, and 4 (two) injuries to her head and face, resulting from the violent jackknifing over the lap belt. 8/ Fortunately, the two children in the rear seat benefited from the wide, firm seats provided in this 1978 Buick station wagon; because of the wideness and firmness of the seats, these children were not able to be injured through either jackknifing or submarining, as children on narrower, softer seats were (see Cases 8 and 10, for example).

In sum, the cases investigated during the Safety Board's project do not support the view that lap-only belts are effective countermeasures against crash injury in frontal collisions. In most of the Board cases, the lap belt itself induced serious to fatal injuries. However, in those cases in which the lap belt did not induce injuries, it does not appear that the lack of induced injuries could be attributed to effective lap belt performance. Furthermore, in these latter cases, either the lap belt failed to prevent other (nonbelt-related) crash injuries or the crash was so mild that few or no injuries were sustained by any occupant, regardless of their seating location or restraint system use. The evidence of these cases however, strongly supports the effective performance of lap/shoulder belts.

STATISTICAL ESTIMATES OF SEAT BELT EFFECTIVENESS

Databases

The Safety Board is aware that the cases investigated in its project are not representative of the range of real-world accidents and, therefore, the findings are not necessarily representative of overall lap belt performance. That is, it may be that if sufficient, accurate data were available on lap belt performance in crashes, it would be shown that lap belts reduce crash losses to a greater extent than they increase them. Unfortunately, the data needed to make such a showing are not available.

As part of this study, the Safety Board examined many studies that have been used in attempts to determine seat belt effectiveness. The types of work done in this area fall into three general categories: observational surveys of restraint use, laboratory tests, and analysis of large databases, most of which are derived from police accident records. Observational surveys, while useful in providing estimates of belt use rates by nonaccident-involved occupants, provide no information on accidents and injuries.

8/ It is useful to compare the types and severity of head and face injuries sustained by this child with those of a girl of similar size seated center front, unrestrained, in a car of similar size and loaded weight, involved in a frontal collision of almost identical Delta V, in Case 34. In that case, the child's most serious head injury was a moderate contusion on her forehead; her most serious injury of any sort was a fractured left leg.

Laboratory tests can provide certain kinds of information about belt performance, but the enormous variations in crash possibilities and human responses cannot be approached in the laboratory, thus severely limiting the significance of laboratory tests for estimating real-world belt performance.

Although the Safety Board's approach, of necessity, involves investigation of a relatively small number of lap belt cases, it has certain distinct advantages over other studies based on large numbers of crashes. Most effectiveness studies are based on analysis of data from police accident reports. Many studies use these police-reported data "as is," accepting their validity at face value. Studies based on one or more States' traffic accident databases are examples of these; the Fatal Accident Reporting System (FARS) of the National Highway Traffic Safety Administration (NHTSA) is another (the FARS database is limited to fatal accidents reported by the police).

Other studies are based on analysis of data from the NHTSA's National Accident Sampling System (NASS) or its predecessor, the National Crash Severity Study (NCSS). These two databases consist of a sample of accidents, drawn from among all police-reported accidents, that were reinvestigated for inclusion in the NASS or NCSS database.

For a variety of reasons, none of these databases (singly or in combination) provide wholly suitable information for estimating the real-world performance of seat belts. The police report databases, for example, contain a number of easily described deficiencies, as discussed in the following sections.

Uncertainties in information on restraint use. In the NCSS database, for instance, the NCSS investigators found that the original police accident reports had, on average, 33 percent "unknown" restraint use; one large State had an "unknown" rate of 85 percent, another 96 percent. 9/

--A review of the FARS database for 1980 showed that for more than 90 percent of the fatalities recorded by California, Indiana, and Illinois police, there was no record of restraint use. 10/

--Some State accident report forms do not even provide space for recording restraint use.

--Despite the high rate of "unknown" restraint use on many State accident forms, the NCSS investigators (and presumably their successors, the NASS investigators) converted the original police information into a database with few "unknowns." An extreme example of this process was one NCSS area in which only 4 percent of the police forms indicated whether a restraint had been used, but the NCSS versions of the same accidents displayed this information in 96 percent of the cases. 11/

9/ S. Partyka, "Corrections for the Effect of Data Source on Restraint Effectiveness Estimates," National Highway Traffic Safety Administration (October 1982), Table C, p. 6.
10/ Ibid., p. 20.
11/ Ibid., p. 8

--The NCSS (possibly also NASS) database also differs considerably from its police report origins on the question of what type of restraint was recorded as used. The police reported lap belt use more frequently than lap/shoulder belt use; the NCSS database, derived from the same accidents, shows just the opposite. (This resulted partly from the fact that the NCSS investigators, in making a decision on a police-recorded "unknown," tended to code more of them as "lap/shoulder belted" than as "lap belted.") As the NHTSA study reporting these facts notes, "This has important implications for the computation of restraint effectiveness rates from police-reported data." 12/

--Among the State report forms that do include an item for restraint use, there is wide variation in the terminology and the options available for marking the type of restraint used. A review of the report forms used in the seven NCSS areas, for example, shows the following options:

Lap belt, harness, lap belt and harness
Belt
No restraint use item
Lap belt, harness
Seat belt, shoulder harness, seat belt and shoulder harness
Strap, belt, strap and belt
No restraint use item

Even assuming the police accurately report which of these many "restraints" were used, it is difficult to translate the terms reliably into the different categories used on Federal databases.

--Lacking (or failing to use) physical evidence of restraint use or nonuse, those who record accident information seem to be guided to some degree, at least, by certain biases. Police, as a group, tend to overreport restraint use by crash survivors (particularly those with minor or no injuries) and underreport restraint use by those killed (or seriously injured). This, of course, "results in high estimates of restraint effectiveness." 13/ Compared to the police reports, NCSS investigators more frequently determined that a seriously or fatally injured occupant was restrained and that an uninjured or only slightly injured person was unrestrained.

What remains completely uncertain, of course, in all of this is what is factually correct. Are the police reports correct on the rate of restraint use by accident-involved persons, or are the "corrected" data of the NCSS/NASS investigators correct? Is the truth somewhere between the two versions? If so, which version is more nearly correct, and how much closer to the truth is it? Obviously, it is critical to know this, because "a small difference in the percentage of restrained occupants may imply a 50 percent difference in the computed fatality rate." 14/

The same substantial uncertainties also exist, of course, concerning what type of restraint was used--an uncertainty with enormous implications for not only the relative effectiveness of various restraints but also whether any given type (lap belt, for instance) is of net benefit at all.

12/ Ibid., p. 10.
13/ Ibid., p. 33.
14/ Ibid., p. 26.

Uncertainties in information on crash severity. Some evidence suggests that the rate of restraint use is lower among accident-involved occupants than among nonaccident-involved, and that this tendency may be more marked as accident severity increases. Without a reliable measure of crash severity, used consistently throughout the data on which the effectiveness estimate is based, the estimate may be biased by the different accident experience of restrained and unrestrained occupants. Estimates of "pre-impact speed" or "impact speed," for instance--commonly used in police reports--are not meant to be precise and do not permit estimation of the crash forces experienced by the vehicle occupants. Thus, the apparent "effectiveness" of restraint systems may be biased by differences in the severities of crashes experienced by restrained and unrestrained people.

Uncertainties in information on injury severity. Many States use broad injury classifications (for example, the KABCO scheme 15/) that are of little use in analyzing restraint systems' potential to reduce (or increase) injury. In KABCO, for example, a broken arm and a broken skull are both coded as "A" injuries, despite their vastly different level of threat to life. Internal injuries (the sort produced by lap belts, for instance) are not likely to be recorded at all. Furthermore, each officer's "definition" of injuries may be different (unlike the superior AIS system, which leaves little or no room for individual bias in coding injuries). Because specific injury data are needed for an accurate estimate of restraint system effectiveness, databases from police-reported information are unsuitable.

Lack of injury source information. The source of injuries is not included in police-reported data. Most police officers are not trained in the collection of such data, nor do they have the time to collect it. However, without these data it is not possible to determine whether, for example, an unrestrained person would have been less severely injured if restrained, or whether the injuries sustained by a lap belted person were caused by the belt itself or in spite of the lap belt.

Lack of injury information. Police reports often do not provide any information on uninjured occupants or those with minor injuries, especially in cases with fatally or seriously injured persons. This is another way in which restraint effectiveness becomes impossible to derive, with any level of confidence, from police-reported data.

Incomplete databases. Police report databases are incomplete. Studies comparing emergency room records and police accident reports have found that only 55 percent of the persons treated in the hospitals for motor vehicle crash injuries were included in police accident reports. 16/ How the addition of the missing 45 percent of injury cases would affect the estimates of seat belt effectiveness that are drawn from such incomplete databases is not known.

15/ In the KABCO scheme, injuries are defined as "K" for any injury that "results in death;" "A" for "severe lacerations, broken or distorted limbs, skull fracture, crushed chest, internal injuries, unconscious when taken from the scene, unable to leave scene without assistance;" "B" for "lump on head, abrasions, minor lacerations;" and "C" for "momentary unconsciousness, limping, nausea, hysteria, complaint of pain (no visible injury)."

16/ J.P. Bull and B. J. Roberts, "Road Accident Statistics--A Comparison of Police and Hospital Information," Accident Analysis and Prevention, 5:45-53, 1973; Jerome I. Baranick and Daniel Fife, "Northeastern Ohio Trauma Study IV: Discrepancies in Vehicular Crash Injury Reporting," Brookhaven National Laboratory (1984).

In addition to these problems in the original police reports, the three large databases which derive from police reports (NCSS, NASS, and FARS) have other drawbacks for estimating restraint performance and net effectiveness.

NCSS. An obvious problem with the NCSS data is that they are aging. They were collected during the 1970's, and since that time, vehicle crashworthiness, restraint system designs, and restraint use have changed considerably.

Second, NCSS data are weighted toward crashes of greater severity. Restraints are more likely to provide benefits (and disbenefits) in these crashes than in, say, non-towaway crashes; but patterns of restraint use may be different among occupants involved in crashes of higher severity from use patterns among occupants in less severe crashes.

Finally, NCSS data uncertainties are compounded by the fact that the second source of information (besides the original police report) for the NCSS investigations--interviews of people acquainted with the accident and/or with its victims--was also plagued by missing data (more than 30 percent, as with the police data). However, the 30 percent missing data were not the same data missing from the police reports. The NCSS investigators tended, furthermore, to "correct" for the missing interview data (or interview data they considered incorrect) differently than they "corrected" the police data.

NASS. The NASS database has the advantage of being more representative of the overall national motor vehicle accident picture than any other database. It includes both towaway and non-towaway accidents. However, the vast majority of accidents--even of towaway accidents--are of such low severity that restraints are not expected to have much, if any, effect (positive or negative). Thus, the majority of NASS cases are not particularly relevant to the question of restraint effectiveness, and must be removed from any sample used to estimate belt effectiveness. However, in most cases they are not removed, and therefore the potential effect of belt use is masked.

The sampling scheme that guides the selection of cases for the NASS database was devised to produce a database representative of U.S. accidents overall. It was not devised to measure the performance of restraint systems. Furthermore, the NASS sampling scheme was devised on the basis that ultimately there would be 75 teams collecting accident cases--a goal the NHTSA has never reached (there are now only 50 NASS teams nationwide). Given the (relatively) small number of crashes in which a restraint system might be expected to have some effect (either good or bad), the even smaller number of crashes in which restraints were used, and the even smaller number of crashes in which lap belts were used, it is not surprising that the NASS sample (the small set of cases which are then "weighted" to represent the national accident population) includes very few cases on which to base lap belt effectiveness estimates.

For example, in 1979 and 1980 combined, the NASS sampling scheme picked up only six persons recorded as fatally injured in a lap/shoulder belt, only one killed in a child safety seat, and none killed in a lap belt. The lap belt "sample" (zero cases) translates into zero cases nationally.

In the 1984 data, looking only at towaway crashes, only three "restrained" rear seat fatalities were captured in the sample (these could have been lap belted, in a child safety seat, possibly in lap/shoulder belts, or some combination of these possibilities). These numbers are simply too small to use for national extrapolations.

FARS. The FARS database is regarded as a census of all fatal accidents. Thus, in theory, it should be useful for estimating restraint effectiveness in reducing fatal injury. The major problem in using it for this purpose is that it is a completely "uncorrected" police-reported database. All the many uncertainties about police-reported data on restraint use pertain to the FARS data.

When the Safety Board reviewed 1984 FARS data for rear seat, belted fatalities, for instance, more than 25 percent of them were reported in FARS as having been killed in rear seat lap/shoulder belts. Probably fewer than 1 percent of passenger cars even have rear seat lap/shoulder belts; it is not possible for 25 percent of those killed in the rear seat while belted to have been using lap/shoulder belts.

Inappropriateness of Databases

Finally, it is important to understand that none of the databases were designed to permit exploration of belt induced injuries. These injuries are indistinguishable, in the databases as currently constituted, from injuries sustained despite use of the lap belt. In contrast, in each case in this Safety Board study it is possible to discern the extent to which the lap belt protected against injury, the extent to which the lap belt was unable to protect against injury, and the extent to which the lap belt itself actually induced injury.

The NHTSA has concluded that the effectiveness of lap belts can be estimated, and that lap belts have a net benefit. For the front seat, the most recent official estimate by the NHTSA 17/ is 30 to 40 percent effectiveness against fatalities, 25 to 35 percent effectiveness against moderate to critical injuries, and 10 percent effectiveness against minor injuries. 18/ For rear seats, the NHTSA estimates 50 to 60 percent effectiveness. 19/ Because of the data weaknesses discussed earlier, the Safety Board is convinced that the available data are inadequate for estimating even the range of possible effectiveness of lap belts.

17/ U.S. Department of Transportation, Final Regulatory Impact Analysis of the Amendment to FMVSS 208: Passenger Car Front Seat Occupant Protection, July 11, 1984.
18/ These are expressions of estimated effectiveness based on 100 percent use compared to zero use. That is, the NHTSA estimates that if there were 100 percent use of lap belts by front seat occupants, there would be 30 to 40 percent fewer front seat fatalities, 25 to 35 percent fewer front seat occupants with moderate to critical injuries (but not killed), and 10 percent fewer front seat occupants with minor injuries, compared to the outcome if no front seat occupants used any restraint. These types of effectiveness estimates cannot be translated into statements such as, "People who use lap belts have 30 to 40 percent less chance of being killed than nonusers."
19/ U.S. Department of Transportation Denial of Retition for Rulemaking (49 FR 15241, April 18, 1984).

RELATED RESEARCH ON LAP BELT PERFORMANCE

The Safety Board reviewed a considerable body of literature related to seat belt performance. Several points emerged from this review.

> The fact that lap belts may induce serious, even fatal, injuries has been known by medical professionals and those working in areas related to motor vehicle safety since the mid-1950's.

A 1967 paper published by researchers at the University of Michigan, for example, noted:

> Although the [lap] belt restraint system has been demonstrated to provide effective reduction of injuries and fatalities in automobile accidents by preventing ejection, with increasing usage of belts by automotive occupants a pattern of injuries directly attributable to impingement on the belt itself is becoming evident. . . .Due to the overall increase in the wearing of belts, the patterns of injuries which may be identified as caused by the belt are becoming clearer. . . . Some idea of the sharp increase in injuries attributed to the seat belt can be found by noting that of the clinical reports referenced in this paper, only three studies occurred prior to 1956, and these were addressed to safety belt injuries in aircraft; yet over 20 clinical reports alone have been concerned with this problem since 1961. . . . [M]ost such cases are probably never reported in the literature. (135) 20/

The author pointed out that the lap belt "has the disadvantage of allowing the head and thorax to swing free in a 'jack-knife' motion during impact" and that it "cannot provide adequate protection to a seated occupant since the upper body components (e.g., head) are free to move during abrupt declerations and strike surrounding structures."

A 1966 paper, published in the Journal of Trauma, noted that "it is evident from the cases . . . in the literature that the [lap] belt is capable of producing a wide variety of injuries." The authors showed that injuries can be sustained even when the belt is worn correctly, and they provided extensive discussion of the type of injuries sustained by lap belted persons, the mechanisms that produce these injuries, and the importance and difficulty of early diagnosis. (170) Many other papers dating from 1956 to 1985 have discussed the problem of lap belt induced injury. 21/ Indeed, early knowledge of the severe limitations of lap belts persuaded safety authorities in some countries not to approve these as acceptable seat belt systems. A 1961 paper by a Swedish safety researcher stated that "the single lap strap does not comply with" the minimum performance requirements the Swedish experts considered essential: "it does not maintain the occupant in an upright position, it does not protect the head and thorax, and it does not hold the vital parts of the body together within the car during an accident--so it has not been considered as a safety belt in Sweden." (4)

20/ The numbers in parentheses shown throughout this section refer to the references listed on pages 39 through 46.

21/ See References 3, 4, 9, 13, 25, 32, 33, 41, 44, 47, 59, 69, 76, 78, 80, 86, 92, 129, 132, 133, 145, 146, 162, and 169.

Lap belts produce characteristic injuries, alone or in combination, and these have been systematically documented since at least 1952.

The characteristic injuries include rupture, perforation, avulsion, transection, laceration/tearing, and fracture of the numerous intra-abdominal organs and their connecting tissue; fracture, dislocation, subluxation, and transection of the spinal column components; a variety of injuries to the cervical spine; numerous types of serious head and facial injuries; fracture of the bones in the pelvic girdle; and abrasion, contusion, and avulsion of the abdominal and hip areas. These have been discussed extensively in many papers. 22/

The injuries characteristically induced by lap belts are of types that are inherently serious, unlike many other types of injuries sustained by crash victims.

The injuries to the spinal column and head that can be induced by lap belt use are obviously very dangerous (see Cases 4, 7, 8, 10, 12, 13, 19, 23, 24, 28, 29, and 30). As for intra-abdominal injuries, a 1966 paper (170) presented an extensive discussion of the variety and gravity of these types in lap belt users, noting that "delays in treatment lead to a high morbidity and mortality." A 1970 paper, after discussing the variety and gravity of intra-abdominal injuries induced by lap belts, reviewed the "patterns of lumbar vertebral injuries associated with lap type seat belts," and noted that "paraplegia results in a significant number of patients." (120)

A 1982 Canadian paper notes that "abdominal injury is . . . one of the most dangerous of all injury types, accounting for 37.8% of injuries at the AIS 4 to AIS 6 level" in the cases studied. These researchers found that "those individuals who were restrained by a single lap belt in the rear seat had a very high incidence of abdominal injuries and in most cases, these were of a more serious nature. . . . The most common cause of abdominal injury is through the intrusion of the belt into the abdomen." (41)

Many of the various types of serious, characteristic injuries induced by lap belts were seen in the Board-investigated cases.

Lap belt induced injuries, particularly those to the intra-abdominal region, are often not immediately apparent; yet delays in treatment can result in long-term disability or even death, so attending medical personnel should suspect internal injury in victims who were belted, or possibly belted.

As early as 1956, medical journal articles began to report cases indicating that lap belt-induced injuries may not be immediately apparent. (76) The delays ranged from 5 hours to 16 months in the medical journal cases reviewed by the Safety Board. 23/ In some of these cases, the victim was able to talk coherently and move about (one man went on from the crash to a ball game before he collapsed). In others, the victim was in discomfort or even pain, but aside from abdominal bruising, evidence of internal injury was not readily apparent for a period of time.

22/ Especially in References 13, 35, 123, 135, 169, and 170.
23/ See References 3, 9, 10, 13, 25, 32, 35, 59, and 69.

In many of these cases, medical personnel attending the victim did not seem to be sufficiently aware of the strong possibility of serious internal injury from the belt itself and did not take the necessary steps to sufficiently explore this possibility. Lacking unmistakable evidence, treatment was delayed, sometimes resulting in long-term disability or death that might have been prevented by more timely intervention. For example, a 61-year-old woman was admitted to a hospital with abdominal bruising evident; the attending medical personnel knew she had been in a car crash while wearing a lap belt. She was complaining of abdominal pain, but her condition "apparently stabilized within a short time," and no further exploration was undertaken until the next morning when she went into shock. At surgery, "a tear in the mesentery of the small bowel with about 12 inches of gangrenous bowel was found. Generalized peritonitis was present as the result of perforation [of the gangrenous organ]. The patient's condition deteriorated rapidly, and she died while on the operating table." (9)

In 1970, researchers at Johns Hopkins University and the Maryland Chief Medical Examiner's Office reviewed the handling of 33 motor vehicle crash deaths in local hospitals between 1964 and 1969. (10) In all these cases the primary injury was intra-abdominal. They found that "half of these lives might have been salvaged by prompt and proper diagnosis and treatment." Nearly half "involved either failure to operate or excessive delay in surgery, despite symptoms of abdominal injury." One-third of the exploratory surgery was not undertaken for more than 12 hours after the victim arrived at the hospital. In at least 21 of the cases there had been "errors or inordinate delay in diagnosis or treatment." The authors concluded: "It is obvious that the key to successful treatment of patients with blunt abdominal trauma is a high index of suspicion and close observation. Early laparotomy should be strongly considered for traffic victims with otherwise unexplained shock and any signs compatible with abdominal injury."

These themes are repeated in the medical literature on lap belt injury victims:

> (1965) -- In all 4 cases presented in this report, evidence of seat belt trauma was externally evident by the contusions across the lower abdominal wall and flanks .... At this time, it would appear worthwhile to be suspicious of lower torso injuries when seat belt markings exist. Furthermore, the insidious nature of ileal perforation would warrant careful observation for abdominal symptoms which cannot be attributed to the abdominal wall contusions. Early exploration in suspicious cases appears to be warranted. (35)

> (1966) -- [E]arly diagnosis and treatment are essential in the management of intra-abdominal safety belt injuries. Furthermore, diagnosis may be difficult because of associated injury or circumstances .... [I]t is important to approach the accident victim who has been wearing a safety belt with a high index of suspicion that he might have an intra-abdominal injury. Historical data regarding the circumstances of the accident should be obtained from the patient or ambulance personnel.... External evidence of trauma conforming to the configuration of the safety belt is helpful in suspecting intra-abdominal injury, but its presence or absence does not confirm or rule out intra-peritoneal trauma. Case 1 in this series had no external evidence of trauma and yet the patient had a perforation of his ileum .... [A] negative [peritoneal tap] should not be interpreted as meaning intra-abdominal injury has not occurred. (170)

(1967) -- Diagnosis is often obscured by the absence of abdominal symptoms and the paucity of physical findings on the initial post-accident examination. Seat belt contusions of the lower abdominal wall, especially about the iliac crests, should alert the examiner to possible intra-abdominal injuries, especially within the lower abdomen and pelvis. (13)

(1967) -- It is of interest that often intra-abdominal injury associated with wearing a safety belt is unsuspected or unrecognized when the patient is first seen after an automobile accident. The physician must be alert to this possibility and observe such an individual carefully. (80)

(1968) -- Abdominal taps and [X-rays] are not dependable when giving negative results. . . . [These cases were written up] to emphasize the significance of the sign of marked contusion in the abdominal area, and to underline the need for maintaining a very high index of suspicion for intra-abdominal injuries. As more patients are saved from ejection . . . by the use of seat belts, physicians will need to become increasingly aware of the possibility of intra-abdominal injuries in victims of automobile crashes. (32)

(1970) -- The extent of intra-abdominal injury may not be as easily perceived . . . . a delay of 24 hours or more occurred in more than 50 percent of the patients. It is also apparent that delay contributed significantly to mortality. Unfortunately, the early clinical findings may be minimal, consisting only of ecchymosis of an abdominal wall. . . . Both delay in laparotomy and the inadvertent production of paraplegia can be avoided by recognizing that the 2 classical components of lap belt injury [intra-abdominal and lumbar spine injuries] may be present concomitantly. Abdominal ecchymosis, signs of peritoneal irritation, even though minimal, and back pain, should alert the attending physican to the combination. (120)

(1971) -- When surgical intervention was undertaken within 12 hours of injury, morbidity was minimal and mortality was low. However, delay of more than 12 hours was accompanied by considerable morbidity and mortality. Deaths were the result of peritonitis with overwhelming sepsis, and were related to delay in diagnosis, the abdominal findings being masked by associated injury. . . . External evidence of belt trauma was present in less than one-third of the patients. Abdominal tenderness on initial examination was present in over 50 percent of the intra-abdominal injuries, and was either overlooked or masked by associated injuries in the remaining cases. The presence or absence of bowel sounds was little diagnostic help. . . . Early peritoneal paracentesis done in 13 cases was positive in only 6 and was falsely negative in 7. . . . [T]he physician must be alert to the injury potential of [the lap belt] when caring for an accident victim who has been wearing such a restraint. Just because an individual has been wearing a lap belt does not mean he is uninjured. (169)

> (1984) -- This case history highlights some important principles in the care of victims of multiple trauma: 1) Rapid evacuation to a centre able to give definitive management is lifesaving. Attempts to stabilize in the field are not likely to be successful and will disadvantage the patient if they cause delay. . . . 3) Surgery often is required to stop severe bleeding. If resuscitation does not reverse shock rapidly and effectively, an undiagnosed injury (with the need for laparotomy) must be considered; prolonged attempts at resuscitation are not successful. 4) Rupture of the diaphragm is always a possibility with chest and abdominal trauma and those patients on whom impressions of a seatbelt are noted are likely to have serious internal injuries. . . . 6) Peritoneal lavage serves only to delay definitive treatment in patients who have clinical signs of abdominal trauma. (162)

In several of the Safety Board-investigated cases there was evidence that the outcome might have been more positive for the lap belt injury victims if the medical personnel handling them had been more suspicious of intra-abdominal injury and had acted promptly and appropriately to determine if this was so and treat the injuries (see especially Cases 6, 8, 17, 27, 28, and 29).

The experience of the 15-year-old boy wearing a lap belt in the right rear seat in Case 27 is an example of the type of medical handling problem referred to throughout the literature of the 1960's and 1970's and especially discussed by Baker in her 1970 paper. This attending physician noted that the boy "experienced immediate deep back abdominal pain" after the crash "but was not unconscious. He was able to walk." Upon arrival at the emergency room, he had "a rigid abdomen" that was "silent"; he was "mildly hypertensive and tachycardic." He vomited in the emergency room and blood clots were noted. He had "normal sensation in all extremities" and his "breathing was normal." During the night he vomited again and bile was noted; he was able to urinate, his urine was clear, and there was no occult blood finding.

By the next day, he was "in acute distress," complaining of "severe abdominal pain." The doctor found "no abdominal scars," but the "abdomen was flat, rigid," and no bowel sounds were heard. The doctor noted "diffuse abdominal tenderness" and "marked tenderness over the midback extending from about T-10 down to L5 but maximal in the central portion with moderate paralumbar spasm. Any back flexion is extremely painful." The doctor's record of this examination states (under a section titled "Impression"): "Rule out compression fracture of the lumbar spine. Rule out possible small bowel or viscus injury. Doubt there is ruptured liver or spleen." No X-rays had yet been taken.

Later that day, the boy was examined by a second doctor. By this time, X-rays had revealed a "Chance fracture" of the lumbar spine at the second and third vertebrae. This doctor's record of his examination states that the boy had received "injuries to the abdomen" that had created an obstruction within his intestine, and that he was "under observation for this."

Eleven days later his abdomen was again distended, he began vomiting again, and exploratory laparotomy was undertaken. It was found that, in addition to the fracture of the lumbar spine, the jejunum had been traumatically perforated in two places, each about 1 inch across, and multiple intraperitoneal abscesses had formed.

Three days after surgical repairs had been made, he became feverish again, and was "acutely ill-appearing" with signs of sepsis and abdominal discomfort. A second consulting doctor noted that he suspected "recurrent sepsis from intra-abdominal pus," that the boy "most likely has an undrained focus of pus." The consulting doctor noted that he expected the boy would need a second laparotomy later that day.

A second operation was performed that day; this time, the boy's ruptured spleen, previously undiagnosed, was removed.

Case 29 also illustrates the need for a deepened awareness among emergency medical personnel of the possibility for belt induced trauma and the urgency of treatment. The man in this case arrived at a hospital with many severe internal injuries. Laparotomy was not undertaken for 4 hours, however; furthermore, no additional surgery was undertaken even though his blood pressure could not be maintained postoperatively. He died within about a day and a half of the laparotomy. At autopsy, fecal matter from a poorly repaired bowel and 4,000 grams of blood clots were found within his abdominal cavity. A blood clot of about 300 grams was found near the liver. A consulting physician told Safety Board investigators that a surgeon trained in treatment of trauma would have undertaken the surgery sooner, would have used more appropriate repair procedures, and would have undertaken additional surgery to correct the continuing problems.

Discussion of other instances of these types of medical handling problems is included in the Safety Board's case summaries in appendix A.

> Some researchers, while admitting that lap belts can induce serious injuries, have claimed that this happens mainly in older, obese women, or only in "high speed" or "severe" crashes, or only if the belt is worn "loosely," or "too high," or only if the wearer "submarines" under the belt.

These are common themes in much of the published work from the 1960's and 1970's, and some of these beliefs are still being expressed in current published work. 24/ Certainly, many of the reported cases said--correctly or incorrectly--that one or more of these elements was involved. Many researchers and other authors seem to have extrapolated from these cases that one or more of these elements was necessary for lap belt induced injury.

However, there has been ample evidence all along that none of these factors is necessary for lap belt injury to occur. Medical articles began appearing as early as 1963 documenting severe belt induced injuries in persons who had almost certainly been wearing the belt snug and low (based on the type and location of their injuries). Papers throughout the period also demonstrated clearly that lap belts were inducing serious injuries in all kinds of people--young and old, of many body sizes, male and female--and in a range of crash severities, with correctly worn and properly functioning lap belts. 25/ Certainly the Safety Board's cases, and several of the Canadian cases presented in appendix B, also clearly demonstrate that this continues to be so.

24/ See References 6, 29, 32, 38, 41, 44, 45, 59, 62, 86, 100, 115, 123, 146, 148, and 172.
25/ See References 3, 9, 13, 32, 35, 36, 37, 38, 44, 59, 69, 76, 78, 80, 82, 123, 135, 145, and 170.

> The primary purpose of lap belts was widely understood in the 1950's and 1960's to be the prevention of ejection, at that time the main cause of motor vehicle crash mortality.

For example, a 1965 paper at the 7th Stapp Car Crash Conference concluded that if all occupants wore lap belts all the time, about 5,000 fewer fatalities would occur solely due to ejection prevention, and that severe injuries could be reduced by about one-third, again in connection with ejection control. (21) A 1966 paper found that "ejection of a crash victim at the time of, or subsequent to, impact is the leading cause of serious injury and mortality resulting from an automobile accident." (170) A 1967 University of Michigan paper stated that "there appears to be relatively universal agreement among researchers as well as clinicians that the major usefulness of any seat belt restraint system is in the prevention of ejection from the vehicle during an impact." (135; emphasis in original). Other papers from that time until the early to mid-1970's drew similar conclusions: that ejection was the single most important cause of crash injury and that the major effectiveness of lap belts was in reducing ejection-caused injury. 26/

The 1965 paper cited, however, went even further, to conclude that lap belts offer no crash protection benefits beyond ejection control:

> [T]here was a hope that [lap] belts would be beneficial beyond the control of ejection. It was hoped that belted occupants would suffer fewer and/or less severe injuries inside the car than their unbelted counterparts, even though neither was ejected. This hope was based on estimates that belted occupants would less often or less violently strike interior objects than would unbelted occupants in a similar accident. (Emphasis in original)

However, after studying 232 matched pairs of crashes (same impact speed, same angle of impact, same make/model car, same physical characteristics of subject occupants, etc.), the authors found that this hope was not fulfilled in the crashes they studied. They concluded:

> In summary, there is a very similar injury situation for [lap] belted and unbelted occupants when consideration is given to performance beyond ejection control. It is found, however, that a different pattern of injury cause emerges as a consequence of being belted. This gives useful clues for seeking countermeasures. . . . [E]fforts for improving restraint systems should be extended to include upper body restraints.

Other studies strongly supported the conclusion that lap belts were not effective at reducing deaths and injuries sustained by nonejected occupants. 27/

Although some research papers found that "seat belts" were effective in reducing even nonejection-related injuries, 28/ most did not distinguish among the "seat belts" in their databases (whether they were lap-only belts, separable lap and shoulder belts, integrated "3-point" lap/shoulder belts, or some mixture of these). The conclusions of these studies, therefore, are not necessarily valid for lap-only belts. Even studies

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26/ See References 9, 13, 21, 32, 39, 65, 135, 164, 169, and 170.
27/ See References 39, 116, 129, 130, and 164.
28/ See References 19, 37, 45, 46, 61, 74, 75, 82, 102, 119, 149, and 163.

that did distinguish among belt types usually failed to take into account basic factors such as collision severity; thus, their conclusion that lap belt use reduced injury severity was not adequately supported (since the lap belted occupants may have tended to be involved in less severe crashes than unrestrained occupants). 29/ Other fundamental flaws marred many of these studies.

Furthermore, some of these studies, while concluding that "seat belts" (or even lap-only belts) are effective in reducing nonejection-related injuries, also found that lap belts induce serious injuries. For example, a 1975 report prepared for the NHTSA looked at computerized crash data on 1,442 lap belted persons and concluded that the lap belted group did better, overall, than the unrestrained group. (37) At the same time, however, the study found:

-- About half of the lap belted occupants, in the front seat and in the rear, who sustained AIS 4-6 injuries, got them from the lap belt itself;

-- 15 percent of the rear seat, lap belted occupants received minor to severe injury from the belt itself;

-- Approximately 47 percent of all the rear seat passenger injuries were due to the lap belt itself. The most frequently injured body part was the abdomen/pelvis, and a snug lap belt was considered responsible;

-- Although the average severity of various injuries was lower when the lap belt was worn snugly, in the case of pelvic girdle, abdominal wall, and abdominal contents, the average severity was higher when the belt was worn snugly;

-- Unbelted persons in the rear were less likely to be injured than lap belted front seat occupants.

Early papers (and some recent ones) often stress that lap belt-induced injuries are "rare." 30/

For instance, a 1979 paper presented at the International Symposium on Seat Belts states: "To conclude, I acknowledge that we have all heard of isolated instances in which belts are supposed to have made the situation worse. We have heard speculations as to various unusual circumstances where the belt is said to be ineffective. Such cases are difficult to trace and vanish like smoke when one tries to locate them." (19) 31/

29/ For example, in two major bodies of motor vehicle crash data, the NCSS and the NASS, the NHTSA found that this was so. In the NCSS data file, in fact, it was found that "restrained occupants were involved in less severe accidents to such an extent that the severity of the accident itself could explain most of the fatality effectiveness." (158) In using these databases to prepare belt effectiveness estimates, the NHTSA attempted to correct for this serious drawback. Many of the other researchers publishing papers on belt effectiveness have not indicated whether such corrections were attempted on their data.

30/ See References 19, 38, 45, 148, and 168.

31/ This paper discusses both lap/shoulder belts and lap-only belts and does not clearly distinguish whether both types, or only one or the other, is being referred to at many points. Such is the case with these statements.

The claim of rarity deserves attention. It is true that there are not hundreds or thousands of documented cases of lap belt induced injury in the literature. However, there may be a number of reasons why this is so.

First, it is worth noting the comment by an experienced occupant restraint researcher in his 1967 paper (135) that most lap belt induced injuries are probably never reported. Given the serious and varied inadequacies in the databases used in many analyses of seat belt performance over the years, it is simply not possible to assert with assurance that these injuries are "rare." Without examination of the vehicles involved, the belt systems, and each occupant's medical records, many injuries may have been unrecorded and others may have been incorrectly attributed to other sources. As noted earlier, lap belt injuries are not necessarily apparent for a time. As is clear from the literature of the 1960's and 1970's, many doctors were not sufficiently aware that lap belts could induce injuries and may not have recorded them as belt induced.

Although the limitations inherent in this study do not permit the Safety Board to accurately estimate the total number of lap belt induced fatalities or serious injuries, the data at least suggest that these problems may not be as rare as many researchers have thought. For example, given the scope of the Board's accident notification system in eight field offices, it is reasonable to assume that the 13 instances of lap belt induced fatalities and 17 more of moderate to critical belt induced injuries may represent approximately 10 percent of all such cases nationally. If this estimate is correct (and it is important to note that it is only an estimate), then there would have been approximately 130 lap belt induced fatalities and 170 belt induced moderate to critical injuries during the same 15-month period. Even if the Board's investigations constitute 25 percent of the cases nationally (which is highly unlikely), then there were 52 such fatalities and 68 such injuries.

The Safety Board is concerned about the problem of lap belt induced injuries because this problem will increase as the passage of mandatory seat belt use laws and other education efforts cause more people to use rear seat lap belts. The loss estimates outlined above reflect the rear seat belt use rates observed in 1984 and 1985--6 percent and 9 percent, respectively, or an average of 7.5 percent. If rear seat belt use rates rise significantly, such as to 15 percent, belt induced fatalities would likewise increase to 260 and moderate to critical injuries to 340.

It is important to understand what these elements represent. There will always be some number of people injured or killed while wearing a seat belt, no matter what belt system is used, because no belt system can protect against all harm and some crashes are simply unsurvivable. This is true of lap/shoulder belts as well as lap-only belts. In those cases, belt use is immaterial--the occupant will either be injured/killed wearing a belt or injured/killed unrestrained. Therefore, as belt use rates increase, the number of people injured or killed while wearing a belt obviously will also increase, because more of the people involved in unsurvivable crash situations will be belted. In these instances, it is not that the belt system brings about injury or death that would not otherwise occur; it is that the belt system in these cases is unable to prevent injury sufficiently. Thus, these cases are not additional injuries and deaths due to increased use rates, they are simply injuries and deaths that move from the unrestrained to the restrained category.

It is not that sort of increase in lap belted injuries/fatalities that concerns the Safety Board. The estimated numbers of lap belt induced injuries and fatalities discussed above represent injuries and fatalities that would not otherwise occur. In other words, they are in addition to the unavoidable injuries and deaths among lap belted occupants (those that the belt is unable to prevent).

Belt systems that include both a lap and an upper torso belt have been widely recognized for many years as providing better overall crash protection, and less inherent hazard, than lap belts.

This is a major theme running through a great deal of the literature from the earliest days of seat belt research and regulation. Although most researchers recognize that even lap/shoulder belts can induce some injuries, they are also recognized as having two major advantages over lap belts alone: they are much more effective at preventing, or reducing in severity, dangerous (non-belt induced) injuries, and the injuries they may produce are typically less severe than those from lap belts. For one thing, the shoulder belt portion prevents the violent jackknifing of the upper body over the lap belt, a motion that can result in severe injuries to the spine, head, and face. For another, the shoulder belt helps to distribute the crash forces over a larger area of the body, rather than concentrating them on the narrow band of vulnerable abdomen covered by even a properly positioned lap belt.

A fleet experiment in the early 1960's in Australia concluded that "the lap belt should not be fitted unless it was impracticable to fit a more effective type." The Australian safety authorities recognized "from the outset, . . . the desirability of requiring seat belts with nondetachable upper torso restraints. This contrasted with the then U.S. approach, where fitting of belts with detachable [shoulder] straps was common." (99)

A 1965 paper presented at the 9th Stapp Car Crash Conference discussed several advantages of the lap/shoulder belt over the lap-only belt and cites communications from experts in England:

> The evidence in this country is, of course, all in favor of the . . . lap/shoulder combination. . . . [W] e have no evidence at all that neck or head injuries have been caused from shoulder straps . . . . Head injuries, on the other hand, have been caused by jackknifing in occupants wearing lap belts alone; these, of course, on occasion, have also been responsible for associated neck injuries due to hyperextension. Shoulder harness would prevent such jackknifing. . . . In the UK, and probably in Europe as well, 3-point lap and diagonal safety belts . . . are the types most frequently fitted to cars . . . . almost no lap belts by themselves are now used . . . . We in the Road Research Laboratory have encouraged the use of safety belts with shoulder restraint as it has been shown that by far the majority of fatal and serious injuries to car occupants are to their heads or chests. We do not think that lap belts can greatly reduce head injuries in frontal impacts because the velocity with which the head can strike the facia is likely to be high when the body is folding about the lapbelt. . . . Our opinion is that the belts with shoulder restraint should always be used. It appears to us significant that the saving in injuries due to the wearing of lap belts in the U.S.A. agrees very well with the saving that would be expected if ejections were prevented; whereas in this country, where almost all seat belts are 3-point belts, the saving in injuries is about three times higher. (129)

A U.S. paper presented at the next Stapp conference (in 1966) compared the impact dynamics of unrestrained, lap belted, and lap/shoulder belted anthropomorphic dummies in sled tests and found that the lap/shoulder belt, "in addition to minimizing or eliminating impact forces [from striking] the vehicle interior, . . . appreciably reduces the forces in the lap belt [acting on the abdomen]." (112)

A 1973 U.S. paper analyzing data on several hundred frontal and side impacts found that front outboard occupants using lap/shoulder belts "were much less likely to have been severely or fatally injured than those with lap belt only. . . . [Those] with lap belts were only somewhat less likely to have been killed than the unrestrained people, but more likely to have been severely injured (AIS 4-5)." The author went on to say that "for both seating positions [driver and right front], the use of a torso device is correlated with a greater reduction in injury than when the person is wearing only a lap belt." (130)

A 1975 paper at the 19th Stapp conference compared injury patterns by type of restraint used. Those using lap/shoulder belts had a greater probability of receiving fewer injuries than lap belted occupants, the researchers found. The rate of facial injuries with lap/shoulder belts was half the rate for lap-only belt users. (94)

The NHTSA sponsored a study in 1976 of 15,000 cars in towaway crashes in several States. Lap belt use by drivers and right front seat passengers reduced their chances of AIS 2 or greater injuries by 31 percent (how much of this reduction was due to ejection prevention alone is not discussed). However, lap/shoulder belts reduced these chances by 57 percent. (119)

Many other such findings of superior lap/shoulder belt effectiveness could be cited, including the NHTSA's own estimates of front seat belt effectiveness, 32/ published in July 1984 as part of the occupant restraint rulemaking proceedings (158):

NHTSA Estimates of Seat Belt Effectiveness (July 1984)

	Manual Lap-only	Manual Lap/Shoulder
Fatalities	30-40%	40-50%
AIS 2-5 Injuries	25-35	45-55
AIS 1 Injuries	10	10

Certainly the injury outcomes observed in the crashes investigated by the Safety Board are consistent with these types of findings. The lap/shoulder belted persons in the Board-investigated frontal crashes, with one exception, were all in the much more vulnerable front seating positions, while the lap belted persons (with only three exceptions) were all seated in the less vulnerable rear seating positions. Even so, a much smaller proportion of the lap/shoulder belted persons received AIS 4, 5, 6, or fatal injuries, compared to the lap belted persons (16 percent compared to 46 percent). All of the fatal injuries, most of the serious injuries, and many of the less serious ones sustained by the lap belted persons were induced by the lap belt itself, whereas the severe or fatal

32/ Three months earlier, in denying a petition from University of Michigan researchers to require lap/shoulder belts in rear outboard seats, the NHTSA had estimated that lap-only belts are 50 to 60 percent effective against fatalities in rear seats. (149) Furthermore, the denial stated that lap/shoulder belts in the rear "would not likely be substantially more effective than this." It is not clear to the Safety Board why lap belts would be so much more effective in rear seats than in front seats (50 to 60 percent, versus 40 percent), nor why lap/shoulder belts would be substantially more effective than lap belts in front seats but not in rear seats.

injuries sustained by the lap/shoulder belted persons were the result of severe intrusion or compartment compression at their seating position, in high Delta V crashes, in which these persons were in a direct line with most of the crash forces. Twenty-five percent of the severely to fatally injured lap belted persons were in crashes of less than Delta V 25 mph; the five lap/shoulder belted persons who received these level injuries were all in severe crashes (Delta V 32-39 mph); the five unrestrained persons who received severe to fatal injuries were also in higher Delta V crashes (1 at 28 mph, 1 at 36 mph, 3 at 43 mph).

Case 13 is useful to consider in this context. In this head-on (slightly left of center) crash of a 1978 Buick stationwagon, the Delta V was 28.9 mph. The driver and the right front seat passenger, both lap/shoulder belted, received AIS 2 and AIS 1 injuries, respectively, as their most severe injuries, while the center front seat passenger wearing a lap belt received an AIS 4 facial fracture, an AIS 3 facial fracture, an AIS 4 skull fracture, and an AIS 2 facial contusion (plus AIS 1 nose fracture and forehead laceration). This 5-year-old boy was similar in size to the 6-year-old boy wearing a lap/shoulder belt next to him.

The experience of the 15-year-old boy lap belted in the rear seat in Case 27 is also instructive. In this Delta V 28 mph crash, this boy (wearing the lap belt correctly) sustained very grave internal injuries and fractures of the second and third lumbar vertebrae, all caused by the lap belt itself; while the two boys in the front seat, using lap/shoulder belts, sustained only minor injuries.

Certainly the 8-year-old girl wearing a lap/shoulder belt in the left rear seat in Case 2 received crash protection superior to that of the many other rear seat occupants in this study who wore only lap belts. She was involved in a severe frontal collision, yet she received only AIS 1 neck and lower abdomen contusions; she was treated and released from a hospital the same day.

Case 29 also illustrates this point vividly. The two persons in the front seat in this frontal collision (Delta V 25.7 mph) sustained no injuries; yet the lap belted man in the rear (less vulnerable) location sustained many moderate to critical internal injuries, resulting in his death.

> Lap/shoulder belts do not present a hazard to children; rather they can provide far superior protection than lap-only belts; they can be used with child safety seats and booster seats.

Several studies have been directed at the question of whether lap/shoulder belts present hazards to children (or other short people). In particular, dangerous injuries to the neck or chest have been suggested as possible outcomes for children wearing 3-point belts.

A Swedish paper examined this question in detail in 1977. (106) Researchers looked at 683 serious crashes in which at least one child younger than 15 years was involved. Of the 822 children involved, 101 were restrained by 3-point lap/shoulder belts (2 were in center front seats, with lap-only belts). For the lap/shoulder belted occupants the findings were:

-- Children were not injured more frequently or more seriously than adults, but less frequently and less seriously;

-- Children did not sustain head, chest, or neck injuries to a greater extent than adults, but to a lesser extent;

- Short occupants, including children, should not be expected to sustain neck injuries caused by the shoulder belt;

-- 3-point lap/shoulder belts have a positive protective/restraining effect on children.

The total injury rate for the lap/shoulder belted children was 16 percent and for the lap/shoulder belted adults was 31 percent. Of the 101 lap/shoulder belted children, 16 were injured: 15 at AIS 1 level, 1 at AIS 2 level. Among the 309 lap shoulder belted adults, 106 were injured, 102 at AIS 1 level, 3 at AIS 2 level, 1 at AIS 4 level. Adults sustained injuries in all major body parts; children, however, sustained no back, abdominal, or hip injuries; children younger than 10 sustained no head injuries. (It should be noted here that in the Board cases, not only did the lap belt fail to prevent head injuries; often it increased the severity of head injuries through the violent jackknifing effect.)

A 1976 Australian study (54) included 20 cases of children younger than 8 years who were restrained by lap/shoulder belts. Although some of them were injured when they were ejected from loosely adjusted belts, the authors concluded: "The use of adult [lap/shoulder] seat belts by children of any age is not a dangerous practice. . . . [C]hildren appear to be afforded good protection by the [lap/shoulder] adult belt even down to 2 years of age as long as the restraint is properly adjusted."

A 1978 Australian study (57) examined alternative crash protection mechanisms for children after their third birthday. The authors concluded: "For the average 3-year-old, the best restraint is [an approved child safety seat], the next is a properly adjusted child's harness, followed by a properly adjusted adult's lap-sash [lap/shoulder] belt." (Note that lap-only belts are not mentioned at all.)

A 1984 British paper (87) reported on dynamic tests to compare the outcome in a 30 mph frontal impact involving a 50th percentile 3-year-old child dummy variously restrained in an adult 3-point lap/shoulder belt, a booster seat with an adult 3-point belt, an approved child safety seat, and a child harness. The researchers concluded: "[The] data suggest that a 3-year-old child is at no greater risk from excess forward movement or inertial forces when restrained in an adult [lap/shoulder] belt than when using a child restraint of proven accident performance." Furthermore, when the same child dummy was restrained by a lap belt only, it experienced "excessive forward movement with a substantial risk of head contact." Use of a lap/shoulder belt-restrained booster seat eliminated "even the small risk" of submarining that was observed for 3-year-olds in lap/shoulder belts.

A 1984 French paper (31) presented test data for child surrogates using 3-point lap/shoulder belts. These were very violent frontal collisions with "very low injury severities" for lap/shoulder belted children; there was no abdominal injury. Even the "quite high position of the shoulder belt did not produce any dangerous loading of the neck, even with some submarining for a small female."

On the question of whether lap/shoulder belts are effective with child safety seats or booster seats, the answer of most researchers familiar with these devices is yes. In 1984, two of these researchers at the University of Michigan petitioned the NHTSA to require 3-point lap/shoulder belts in rear outboard positions of passenger cars. One of their main arguments was that lap/shoulder belts work effectively with child safety seats and booster seats and would eliminate the need for top tethers on these devices (failure to install and attach top tethers is the commonest form of misuse in devices that require

them). Provision of lap/shoulder belts would also benefit the majority of children who are not in any kind of child restraint device (because their parents have not provided one or because they are too large to use one) and adults who use the rear seat.

The NHTSA denied this petition, however. (149) The NHTSA said it does not agree with the petitioners' argument that child booster seats used with lap/shoulder belts are as effective as booster seats equipped with their own shoulder harnesses. The agency said that both children and adults can withstand greater forces on their shoulders than on their chests, and that "very young children" in particular have chest cavities that are "very flexible and vulnerable to chest belt loads," the sort of loads that lap/shoulder belts "would create." Harnesses provided with booster seats would "concentrate loads on the more sturdy shoulders of children."

The concern expressed by the agency about chest loads induced by lap/shoulder belts is, however, at variance with the evidence presented by the research papers noted above and by the experience of the children using lap/shoulder belts in the Safety Board's accident cases. Whether or not children's shoulders can bear greater loads than their chests, there was no evidence in the studies or the Board's cases that children were injured by the chest loads that may have been induced. Indeed, the children in the Swedish lap/shoulder belt study sustained fewer, and less severe, chest injuries than the adults; none sustained greater than AIS 2 injuries of any sort (only one child received AIS 2 level injuries). The same was true of the children using lap/shoulder belts in the Board's cases, all of whom were in severe frontal collisions.

Furthermore, the NHTSA's argument assumes that shoulder harnesses provided with some types of booster seats are in fact being used and used properly. Before using these harnesses, a tether anchorage system must be installed and the harnesses must then be attached to the tether anchor. An earlier Safety Board study 33/ noted that most child safety seats that require a tether do not, in fact, have the tether attached. Thus, most children using these booster seats do not have a properly attached shoulder harness in place; they are riding on the booster seat either totally unrestrained or, worse yet, restrained with a lap belt. (Use of a lap belt alone with a booster seat that requires a tethered harness is a very hazardous way to transport children.)

Finally, it should be noted that the types of booster seats discussed by the NHTSA have now been replaced in the market by booster seats with only a small shield in front of the child. When these boosters are used with only a lap belt around them (as they must in the rear seats of American cars and some foreign models), there is risk of abdominal injury, according to research recently conducted at the University of Michigan. If these boosters were used with lap/shoulder belts, the research showed, the risk of abdominal injury would be minimal, due to upper torso restraint provided by the shoulder belt.

The NHTSA also said that using a lap/shoulder belt with child safety seats would be "much less convenient" than using a lap-only belt. The reasoning behind this argument is not apparent to the Safety Board. Child safety seats are frequently used in the front outboard positions of American cars, where lap/shoulder belts are required by the NHTSA. According to a national child occupant protection organization, the Physicians for Automotive Safety, NHTSA-sponsored research has in fact shown that using the shoulder belt portion enhances the stability of the child safety seat, decreasing head excursion.

33/ Safety Study--"Child Passenger Protection Against Death, Disability, and Disfigurement in Motor Vehicle Accidents" (NTSB/SS-83/01).

FEDERAL REGULATIONS AND MANUFACTURERS' PRACTICES ON MOTOR VEHICLE SEAT BELTS

Beginning with the first Federal Motor Vehicle Safety Standard (FMVSS) regulating occupant restraint systems in the United States, lap/shoulder belts have been required for the front outboard positions, while only lap belts have been required for the center front seat and all rear seat positions. No U.S. manufacturer has voluntarily provided any other configuration, 34/ although many foreign cars have provided lap/shoulder belts at rear seating positions for several years. Indeed, in the earliest days of Federal regulation of seat belts, several U.S. manufacturers opposed any requirement for shoulder belts, even in front seating positions. General Motors (GM), for example, said:

> [W]e believe shoulder belts should continue to be offered [only] as optional equipment . . . we believe it would be premature and undesirable to require the installation of shoulder belts in all passenger cars . . . . Little is known about the safety utility of shoulder belts . . . . General Motors knows of no reliable statistical data on shoulder belts. (GM comments on Docket No. 3, Notice 1, December 30, 1966)

Ford Motor Company (Ford) also opposed requirements for front seat shoulder belts:

> Shoulder belts should be optional rather than mandatory equipment . . . . A carefully and individually adjusted shoulder belt does make some contribution to safety, but a poorly adjusted belt may introduce new hazards and proper adjustment cannot be made in every case. (Ford comments on Docket No. 3, Notice 1, March 2, 1967)

American Motors Corporation (AMC) was in agreement with GM and Ford on this point: "The available evidence on the safety benefits of [lap/shoulder] belts is not conclusive enough to support a mandatory requirement." (AMC comments on Docket No. 3, Notice 1, December 24, 1966) The Automobile Manufacturers Association (AMA) (now the Motor Vehicle Manufacturers Association) seemed to disagree with GM about the known safety benefits of lap/shoulder belts over lap-only belts, but opposed a requirement for them nevertheless:

> AMA does agree that significant safety benefits would be derived from the development and installation of improved upper torso restraint systems. Such systems could go a long way toward alleviating many of the problems of occupant interior impact. However, shoulder belts are still generally uncomfortable, unpopular and unused by the public. (AMA comments on Docket No. 3, Notice 1, January 3, 1967)

However, the NHTSA was not apparently swayed by these arguments; the first Federal standard required that the front outboard positions have (detachable) shoulder belts in addition to lap belts.

34/ In June 1986, General Motors announced that it will begin providing lap/shoulder belts at rear outboard positions in selected 1987 and 1988 passenger vehicles and in all remaining passenger vehicles during model year 1989. In July 1986, Ford Motor Company announced that it plans to introduce lap/shoulder belts at rear outboard positions during the next few years.

So far as the Safety Board can determine, the possibility of requiring lap/shoulder belts at rear outboard positions has been considered on only two occasions in the rulemaking history of FMVSS 208: Occupant Crash Protection. The first occurred very early in the regulation's history, in the course of the first significant revision of the initial standard. In 1970, the NHTSA published a proposal to begin moving away from active, or manual, seat belt systems toward passive, or automatic, occupant crash protection systems (such as air bags). In the interim stage before the proposed beginning date for passive system requirements, however, the agency proposed to require, "at all seating positions," seat belts "including upper torso restraints." (Docket 68-7, Notice 4, 35 FR 7187, May 7, 1970) This requirement for lap/shoulder belts at every seating position, front and rear, would apply only to vehicles manufactured between January 1, 1972, and January 1, 1973 (at which time, the agency proposed, the requirements for passive protection would come into effect).

Statements from the NHTSA and from those who commented on this proposal suggest that the interim lap/shoulder belt requirements were given little attention. The agency's views were reflected in its statements at a public meeting held by the NHTSA during the rulemaking comment period:

> We feel that the time of passive occupant crash protection is upon us and we do not intend to further pursue, beyond 1972, what has been a generally unpopular and futile effort to employ active restraint systems as a means of protecting occupants in crashes. [Statement of Ralph Hitchcock, then Product Engineer at NHTSA, at meeting held June 24 and 25, 1970]

This attitude appears to have been shared by auto manufacturers and others who commented on the proposal. For example, even though the auto makers opposed the passive restraint proposal, they did not comment extensively on the proposal to require lap/shoulder belts at all seating positions. Most of the comments on belt requirements addressed the question of whether lap/shoulder belts should be integrated, 3-point systems (rather than the then-current systems with detachable shoulder belts), and there was no differentiation in their comments between requirements for front and rear seats, or front outboard versus center front.

Two commenters did address the issue of requiring lap/shoulder belts in all seating positions. A seat belt manufacturing company opposed requiring them in the rear seats because, they said, rear seat occupants "are afforded ample protection by their location and other factors" and that rear seat occupants were able to survive severe crashes because of the padded front seatbacks in front of them. The other comment was submitted by the Motor Vehicle Safety Advisory Council of the U.S. Department of Transportation, which argued that this proposal would be too costly and lap/shoulder belts should be required only for drivers.

In all the later stages of this proposal, including the publication of the "final rule" on March 10, 1971 (36 FR 4600), the requirement for shoulder belts was limited to the front outboard seating positions. There was no discussion or explanation of why the proposal to require them at all seating positions had been dropped, and seat belt requirements have remained in this basic configuration to this day.

The only other point at which there appears to have been official consideration of the concept of requiring lap/shoulder belts at rear seating positions came as a result of the petition from researchers at the University of Michigan in 1984, discussed in an earlier section of this report.

Since 1972, the NHTSA has required that manufacturers provide an anchor location for after-market installation of separate, detachable shoulder belts at rear outboard positions. These are simply holes drilled into solid metal somewhere within the acceptable area defined by FMVSS 210, and they are not easily detectable. The Safety Board examined current owner's manuals for American and some foreign cars and found that none mentioned the existence of this anchorage. The manuals for GM models did note that shoulder belts are available. The GM manuals note that, "when properly worn with a lap belt, a shoulder belt can give riders added protection. It can prevent or reduce impact with the inside of the car by restraining the upper body in a collision. This is especially true in a frontal collision." Apparently only GM makes these belts available as a dealer-installed option; it is not certain whether GM shoulder belts could be used in other companies' models. Even to install these in GM cars requires removal of the original lap belts and installation of new lap belts with a "keyhole" suited for the insertion of the nonretractable shoulder belt.

Many foreign models (Audi, BMW, Honda, Jaguar sedan, Mercedes-Benz, Peugeot, Rolls Royce, Saab, some VWs, and Volvo) provide 3-point lap/shoulder belts in rear outboard positions, even though U.S. regulations do not require them. Of course, these systems have been required in several countries for many years (Sweden, Australia, and Germany most notably; see appendix I). A recently introduced "captive import," the Merkur XR4 Ti, also provides rear seat lap/shoulder belts, as will the second Merkur model, the luxury sedan Scorpio. In addition, as noted earlier, GM and Ford recently announced plans to begin providing rear seat lap/shoulder belts.

CONCLUSIONS

Based on the information collected by the Safety Board in its special crash investigation program and corollary research, summarized in this study report, the Board concludes the following:

- In frontal collisions, persons using lap-only belts may not be adequately protected against injury and may sustain additional injuries, induced by the lap belt itself.

- Lap belts may induce injury, ranging in severity from minor to fatal, to the head; spine; abdomen; intra-abdominal viscera, connecting tissue, and blood vessels; and intra-thoracic viscera, connecting tissue, and blood vessels. Such injuries may occur singly or in combination.

- The types of injuries induced by lap belts can be difficult to diagnose, particularly if attending medical personnel are unfamiliar with the symptoms or are unaware that serious injury can be belt induced; in some cases, symptoms of belt induced injury may not become apparent for some time. Inadequate medical treatment may also occur if attending medical personnel have been misinformed about the patient's use or nonuse of a belt system, about the type of belt system used, about whether the patient was ejected during the crash, or about other important facts of the crash.

- The gravity of typical lap belt induced injuries is such that if appropriate treatment is not provided quickly, serious irreversible consequences, including death, may result; some physicians advise that medical personnel attending a motor vehicle crash victim should suspect serious injury has occurred, particularly if lap belt use is known or suspected, and to act quickly to explore this possibiity and begin appropriate treatment.

- Because of a variety of weaknesses in available accident databases, it is not possible to determine the overall effectiveness of lap belts in preventing fatalities and reducing injury; the Safety Board is unable to state with confidence whether passenger vehicle occupants should be advised to use rear seat lap belts or not.

- The relative inadequacy of lap belts to provide crash protection, and their ability to induce serious injury, have been known for many years to researchers, some parts of the medical profession, and to others concerned with occupant crash protection.

- Lap/shoulder belts provide superior crash protection to that of lap belts alone, and present a significantly lesser risk of induced injury; such systems appear to work effectively even for children, and they can be used with child safety seats and booster seats.

- The U.S. Federal Motor Vehicle Safety Standards have required since the early 1970's that front outboard seating positions in passenger vehicles be fitted with 3-point lap/shoulder belts; however, all other seating locations may be fitted with a lap-only belt.

- Most manufacturers have not provided 3-point lap/shoulder belts at any seating location except the front outboard, where they are required.

- Since the early 1970's, the U.S. Federal Motor Vehicle Safety Standards have required that anchor locations for the after-market installation of detachable shoulder belts be provided at the rear outboard seating locations of passenger cars. However, few manufacturers note this fact in the owner's manuals for their cars and it is unlikely that many car owners are aware of it. So far as the Board could determine, only General Motors sells a detachable shoulder belt that could be fitted at the anchor locations.

- Several countries require that 3-point lap/shoulder belts be provided at rear outboard seating locations; several foreign manufacturers provide such systems even in vehicles manufactured for sale in the United States.

Given the known deficiencies of lap-only belt systems and the superior crash protection offered by belt systems that incorporate an upper torso restraint, the Safety Board believes that government and industry should take a number of steps to reduce reliance on lap belts and increase the availability of lap/shoulder belt systems. The implementation of State mandatory belt use laws will inevitably increase pressure for

more widespread use of belt systems in other than front seat locations. Indeed, at this writing, two States have passed laws that require all passenger vehicle occupants to wear the belts available to them; three more States require children to use belts in the rear seats (and some State laws on use of child restraint devices permit the alternative use of lap belts).

Therefore, the Safety Board believes that early action should be taken by the motor vehicle industry to provide aftermarket retrofit assemblies to convert lap-only belts to lap/shoulder belts. As mentioned above, attachment points for the upper anchor location have been required for more than 10 years at rear outboard locations; at least one domestic manufacturer also makes a separate, detachable shoulder belt available for aftermarket installation at these anchor locations. At a minimum, such retrofit assemblies should be available for all passenger vehicles required to be equipped with the necessary upper anchor locations, and manufacturers should aggressively market these systems and encourage owners to have them installed.

However, rather than merely supplementing the lap belts at these outboard locations with an add-on shoulder belt, manufacturers should provide integrated, continuous loop, self-storing lap/shoulder belt systems to replace the outboard lap belts entirely. These systems are preferable because they will be far more comfortable and convenient to use and are thus more likely to be used than the more awkward, cumbersome system created by merely adding a separate shoulder belt to existing lap belts.

For newly manufactured passenger vehicles (automobiles and multipurpose vehicles), all rear outboard seating positions should be equipped with integrated, continuous loop, self-storing lap/shoulder belts. The reasons for this are similar to those for urging an aggressive program of retrofit: increasing use of seat belts due to State laws, the inferior performance of lap-only systems, and the greater overall crash protection offered by lap/shoulder belts. Many foreign car models have provided these systems for some time, and some countries have in fact required their installation. Two U.S. manufacturers have announced plans to begin providing them. The Safety Board believes that there is no reasonable justification for continuing to forego these improvements in all passenger vehicles sold here.

Furthermore, the Safety Board believes that it may be technically feasible to provide 3-point lap/shoulder belts at every seating location; if so, such systems should be required as soon as possible. As long ago as the early 1970's, the NHTSA proposed such a requirement, at least for passenger cars.

There are a number of ways in which shoulder belts at nonoutboard seating locations could be attached. Some of the passenger cars that already provide 3-point lap/shoulder belts in rear outboard positions attach the upper anchor to the "rear deck" or "parcel shelf" behind the rear seat; a third shoulder anchor also could be located in this area. In such vehicles as vans, the upper anchor for shoulder belts might be located in the back of the seat itself, or they could be floor anchored if care were taken not to interfere with the foot area of the persons in the next seat behind. The Safety Board believes passenger vehicle manufacturers and the NHTSA should research this concept in depth, and should provide these restraints for every seating position if it is possible to do so.

It may be argued that the center front and center rear seating locations in passenger cars have the lowest rates of occupancy, and that therefore it is not warranted to provide the superior protection of lap/shoulder belts at these locations. The Safety Board believes that, to the extent these seating locations are used, their occupants deserve crash protection equal to those provided for other occupants. Furthermore, most of the seating locations in vehicles such as passenger vans are just such nonoutboard positions; as the two van cases in the Board's study vividly illustrate, persons using lap belts in such vehicles may be receiving substantially less crash protection even than persons altogether unrestrained.

Since designs for installing lap/shoulder belts at every seating location may require more vehicle modifications than either of the other two steps outlined above, the Safety Board realizes that more time may be required for implementation of this step. Nevertheless, the Board believes it is important to move as rapidly as possible to bring about the necessary design modifications to make such systems available to every occupant of passenger vehicles in this country.

Finally, the Safety Board believes that many emergency medical personnel, including those operating ambulance service, police or fire rescue personnel, emergency room nurses and physicians, and others called on to treat motor vehicle crash victims remain unaware of the possibility and gravity of seat belt induced injuries. Although the Board found many articles in leading medical journals concerning this problem, it appears that there is still a widespread lack of understanding in this area. In 6 cases reviewed by the Board, out of the 26 in which a lap belted person was involved (nearly 25 percent), there was serious question about the adequacy of the medical handling of the lap belted victim. In some there was little doubt that poor diagnosis and inadequate treatment contributed to the death of a person who might well have survived with prompt, appropriate treatment. As more people begin to use their belt systems, it will be very important for the medical community to educate itself about the type of injuries they may be called on to diagnose and treat, and take action to ensure that this knowledge is rapidly and effectively disseminated to those who will need it.

RECOMMENDATIONS

As a result of this safety study, the National Transportation Safety Board made the following recommendations:

--to U.S. manufacturers of passenger vehicles:

> Provide aftermarket retrofit assemblies for passenger vehicles to convert lap-only belt systems at outboard positions to integrated, continuous loop, self-storing lap/shoulder belt systems; make the availability of these retrofit systems widely known to vehicle owners and installation of them as simple and inexpensive as possible. (Class I, Urgent Action) (H-86-38)
>
> Provide, on a voluntary basis, in newly manufactured passenger vehicles, integrated, continuous loop, self-storing lap/shoulder belts in all non-front outboard seating positions. (Class II, Priority Action) (H-86-39)

Cooperate with the National Highway Traffic Safety Administration in determining the technical feasibility of providing lap/shoulder belts at non-outboard seating positions of passenger vehicles, and work toward providing such systems in newly manufactured vehicles at the earliest practicable time. (Class II, Priority Action) (H-86-40)

--to foreign manufacturers of passenger vehicles:

For any passenger vehicles with lap-only belts at outboard positions, provide aftermarket retrofit assemblies to convert these belts to integrated, continuous loop, self-storing lap/shoulder belt systems; make the availability of these retrofit systems widely known to U.S. vehicle owners and installation of them as simple and inexpensive as possible. (Class I, Urgent Action) (H-86-41)

Provide, on a voluntary basis, in newly manufactured passenger vehicles that do not already have them, integrated, continuous loop, self-storing lap/shoulder belts in all non-front outboard seating positions. (Class II, Priority Action) (H-86-42)

Cooperate with the National Highway Traffic Safety Administration in determining the technical feasibility of providing lap/shoulder belts at non-outboard seating positions of passenger vehicles, and work toward providing such systems at the earliest practicable time in newly manufactured vehicles sold in the United States. (Class II, Priority Action) (H-86-43)

--to the National Highway Traffic Safety Administration:

Encourage manufacturers of passenger vehicles to provide aftermarket retrofit assemblies to convert lap-only belt systems at outboard positions to integrated, continuous loop, self-storing lap/shoulder belt systems; urge manufacturers to make the availability of these retrofit systems widely known to vehicle owners and installation of them as simple and inexpensive as possible. (Class I, Urgent Action) (H-86-44)

Require that lap/shoulder belts be installed at all outboard seating positions in newly manufactured passenger vehicles manufactured for sale in the United States; initiate rulemaking action to this end immediately. (Class I, Urgent Action) (H-86-45)

Until such time as they are required to do so, encourage manufacturers of passenger vehicles to provide, on a voluntary basis in newly manufactured vehicles, integrated, continuous loop, self-storing lap/shoulder belts in all non-front outboard seating positions. (Class II, Priority Action) (H-86-46)

Determine the feasibility of requiring that 3-point lap/shoulder belts be provided at every seating position in newly manufactured passenger vehicles manufactured for sale in the United States; if found technically feasible, undertake rulemaking to require such lap/shoulder belts. (Class II, Priority Action) (H-86-47)

--to the International Association of Chiefs of Police:

Disseminate information to your members on the possibility for serious head, spine, and internal injuries to motor vehicle crash victims who were using a lap belt; ensure that your members are aware that these injuries, particularly internal injuries induced by lap belt use, may not be apparent for some time, and that it may be prudent even for seemingly uninjured lap belt users to be provided early medical attention by physicians familiar with treatment of trauma. (Class II, Priority Action) (H-86-48)

--to associations and groups concerned with emergency medicine:

Through communication with your organization's members and with other medical personnel, disseminate informed guidance to those called on to treat motor vehicle crash victims concerning the nature, severity, and appropriate handling of injuries that can be sustained by those using belt restraint systems. Ensure that emergency medical personnel receive training on the internal, head, and spine injuries that should be suspected in the case of crash victims who were using a lap belt, and the urgency of proper diagnosis and treatment. Encourage those emergency personnel who transport injured crash victims to relate accurate information to hospital emergency room personnel concerning the circumstances of the victim's involvement in the crash (seating location, use or nonuse of seat belt, type of belt used, etc.) (Class II, Priority Action) (H-86-49)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ PATRICIA A. GOLDMAN
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/s/ JIM BURNETT
Member

/s/ JOHN K. LAUBER
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/s/ JOSEPH T. NALL
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July 28, 1986

REFERENCES

1. Adomeit, Dieter. Seat Design -- A Significant Factor for Safety Belt Effectiveness (SAE 791004).
2. _____ and Appel, H. Influence of Seat Design on the Kinematics and Loadings of the Belted Dummy. IRCOBI (1979).
3. Aiken, D.W. Intestinal perforation and facial fractures in an automobile accident victim wearing a seat belt. J. Louisiana State Med. Soc. 115:235, 1963.
4. Aldman, Bertil. The Value of the Automobile Safety Belt. International Road Safety and Traffic Review, Vol. IX, No. 2, Spring 1961.
5. Almqvist, Rune et al. Frontal Crash Protection in a Modern Car Concept. IXth Experimental Safety Vehicle Conference, Kyoto (1982).
6. American Academy of Pediatrics. Lap belts for youngsters: implications for counseling and legislation. Safe Ride News, Vol. II, No. 1 (October 1982).
7. Arkoino, P.L. Dynamics of the Belted Occupant, Implications for Protection. In, Aldman, B. and Chapon, A. (eds): The Biomechanics of Impact Trauma. International Center for Transportation Studies (Elsevier Science Publishers, Amsterdam: 1984).
8. Avery, J.G. Seat belt success: where next? Br. Med. J. 288:662, 1984.
9. Backwinkel, K.D. Injuries from seat belts. J. Am. Med. Assn. (JAMA) 205:305, 1968.
10. Baker, Susan et al. Traffic Deaths Due to Blunt Abdominal Trauma. Proceedings, 14th Annual Conference of the American Association for Automotive Medicine (AAAM), Ann Arbor (1970).
11. Barancik, Jerome I. and Fife, Daniel. Discrepancies in Vehicular Crash Injury Reporting: Northeastern Ohio Trauma Study IV (1984).
12. Birrell, J.H.W. Med. J. Aust. Vol 1, No. 3.
13. Blumenberg, R.M. The seat belt syndrome: sigmoid colon perforation. Ann. Surg. 165:637, 1967.
14. Bohlin, Nils I. A Statistical Analysis of 28,000 Accident Cases with Emphasis on Occupant Restraint Value. Proceedings, 11th Stapp Car Crash Conference, Society for Automotive Engineering (SAE), New York (1967).
15. _____. Refinements of Restraint System Design -- A Primary Contribution to Seat Belt Effectiveness in Sweden. International Symposium on Occupant Restraints, Toronto (AAAM, 1981).
16. Bondy, Nancy. Abdominal Injuries in the National Crash Severity Study. In, Collected Technical Studies, Vol. II: Accident Data Analysis of Occupant Injuries and Crash Characteristics -- Eight Papers, National Center for Statistics and Analysis, U.S. DOT (1981).
17. Brink, D.C. Spinal cord injuries and seat belts. Med. J. Aust. 2:801 (1973).
18. Cameron, H.M. and Nelson, P.G. Injury Patterns With or Without Seat Belts. Proceedings, 6th International Conference of the Association for Accident and Traffic Medicine (1977).
19. Campbell, B.J. Seat Belt Effectiveness. International Symposium on Seat Belts, Tokyo (1979).
20. _____. The automotive crash injury research program of Cornell University. J. Iowa Med. Soc. 51:760 (1961).

21. _____ and Kihlberg, Jaakko K. Seat Belt Effectiveness in the Non-Ejection Situation. Proceedings, 7th Stapp Car Crash Conference (1965).
22. Campbell, H.E. Role of the safety belt in nineteen auto crashes. Bull. Am. Coll. Surg. 40: 155 (1955).
23. _____. The automobile seat belt and abdominal injury. Surg. Gynec. Obstet. 119:591 (1964).
24. Christian, M.S. Non-fatal injuries sustained by seat belt wearers: a comparative study. Br. Med. J. 2:1310 (1976).
25. Cocke, W.M., Jr., and Meyer, K.K. Splenic rupture due to improper placement of automobile safety belt. JAMA 183:693 (1963).
26. Dajee, H. and MacDonald, A.C. Gastric rupture due to seat belt injury, Br. J. Surg. 69:436 (1982).
27. _____ et al. Seat belt aorta: acute dissection and thrombosis of the abdominal aorta. Surgery 85:263 (1979).
28. Dalmotas, D.J. et al. Current Activities in Canada Relating to the Protection of Children in Automobile Accidents (SAE 840529). In, Advances in Belt Restraint Systems: Design, Performance and Usage, Detroit (1984).
29. Dance, M. et al. An In-Depth Analysis of a Multiple-Fatal, Head-On Motor-Vehicle Collision. Proceedings, 25th AAAM conference, San Francisco (1981).
30. DeRosa, D. and Larsonneur, J.F. Seat Belt Improvements (SAE 840400). In, Advances in Belt Restraint Systems: Design, Performance and Usage, Detroit (1984).
31. Desjeammes, Maryvonne et al. Exploration of Biomechanical Data Towards a Better Evaluation of Tolerance for Children Involved in Automotive Accidents (SAE 840530). In, Advances in Belt Restraint Systems: Design, Performance and Usage, Detroit (1984).
32. Doersch, K.B. and Dozier, W.E. The seat belt syndrome: the seat belt sign, intestinal and mesenteric injuries. Amer. J. Surg. 116:831 (1968).
33. DuBois, E.F. Safety belts are not dangerous. Br. Med. J. 2:685 (1952).
34. Finch, D.M. and Palmer, J.D. Dynamic Testing of Seat Belts. Preprint No. 48, for presentation at SAE Summer Meeting, Atlantic City (1956).
35. Fish, J. and Wright, R.H. The seat belt syndrome — does it exist? J. Trauma 5:746 (1965).
36. Fisher, P. Injury produced by seat belts: report of two cases. J. Occupat. Med. 7:211 (1965).
37. Flamboe, Eugene E. A Comparison of Injuries Between Lap-Belted and Non-Restrained Automobile Occupants According to Seated Position and Vehicle Size (DOT-HS-801-350), January 1975.
38. Fletcher, B.D. and Brogdon, B.G. Seat-belt fractures of the spine and sternum. JAMA 200:177 (1967).
39. Frazier, R.G. Effectiveness of seat belts in preventing motor vehicle injuries. N. Eng. J. Med. 264:1254 (1961).
40. Fulton, J.L. Seat Belts Versus Shoulder Harness (SAE 660536).
41. Gallup, B.M. et al. Abdominal Injuries to Restrained Front Seat Occupants in Frontal Collisions. Proceedings, 26th AAAM conference, Ottawa (1982).
42. _____ et al. The Development of Two Prototype Seat Belt Systems for Improved Lap Belt Fit. Proceedings, 28th AAAM conference, Denver (1984).

43. _____ et al. The Relationship Between Belt Fit and Abdominal Injuries to Rear Seat Occupants. Proceedings, 4th Canadian Multidisciplinary Highway Safety Conference, Montreal (1985).
44. _____ et al. Untitled. "Preprint" for 1985 SAE Conference.
45. Garrett, J.W. and Braunstein, P.W. The seat belt syndrome. J. Trauma 2:220 (1962).
46. Garvin, G. Children in Injury Level Accidents. Proceedings, 20th AAAM conference, Atlanta (1976).
47. Gerritsen, R. et al. Unusual abdominal injuries due to seat belts. J. Albert Einstein Med. Ctr. 14:63 (1966).
48. Grattan, E. and Hobbs, J.A. Some Patterns and Causes of Injury in Car Occupants. Proceedings, 5th International Technical Conference on Experimental Safety Vehicles (1974).
49. Green, R.N. et al. Investigation of Injury Mechanisms Associated with Fully Restrained Passenger Vehicle Occupants in London, Ontario. Proceedings, 21st AAAM conference (1977).
50. Grime, G. Information on Injuries Obtained from Reports of Accidents to Car Occupants Wearing Safety Belts. Proceedings, Conference on Road Safety, Foundation for Road Safety Research, Brussels (1968).
51. Haddad, G.H. and Zickel, R.E. Intestinal perforation and fracture of lumbar vertebra caused by lap-type seat belt. N.Y. State J. Med. 67:930 (1967).
52. Hartemann, F. and Tarriere, C. How to Further Improve the Protection of Occupants Wearing Seat Belts. Proceedings, 19th AAAM conference (1975).
53. Henderson, J.M. and Freedman, K. The Effect of Mandatory Seat Belt Use in New South Wales, Australia. Proceedings, 17th AAAM conference, Oklahoma City (1973).
54. _____ et al. Performance of Child Restraints in Crashes and in Laboratory Tests. Proceedings, Seat Belt Seminar, Melbourne (1976).
55. _____ et al. The Effect of Seat Belt Design and Anchorage Geometry on Injury Patterns. Proceedings, 6th International Conference of IAATM, Melbourne (1977).
56. Herbert, D.C. Injury reduction by diagonal and other vehicle safety belts. Med. J. Aust. 1:61 (1964).
57. _____ and Cutting, D. Crash Protection for Children After Their Third Birthday. Dept. of Motor Transport, New South Wales (1978).
58. Hobbs, C.A. Car Occupant Injury Patterns and Mechanisms. Proceedings, 8th International Technical Conference on Experimental Safety Vehicles. Wolfsburg (1980).
59. Howland, W.J. et al. Fulcrum fractures of the lumbar spine. JAMA 193:240 (1965).
60. Huelke, D.F. Effectiveness of Occupant Restraints in Reducing Serious Injuries and Fatalities. International Symposium on Occupant Restraint, Toronto (AAAM, 1981).
61. _____. Study of 139 Accidents Involving 177 Fatalities. Highway Safety Research Institute, University of Michigan (1961).
62. _____. The Effectiveness of Belt Systems in Frontal and Rollover Crashes (SAE 770143).
63. _____. The Rear Seat Automobile Passenger in Frontal Crashes. Proceedings, 22d AAAM conference (1978).
64. _____ and Chewning, W.A. Comparison of Occupant Injuries With and Without Seat Belts (SAE 690244).

65. _____ et al. Injury Causation in Rollover Accidents. Proceedings, 17th AAAM conference, Oklahoma City (1973).
66. _____ and Lawson, Thomas E. Injuries to Rear-Seat Passengers in Frontal Automotive Crashes. The HSRI Research Review, Vol. 9, No. 1 (1978).
67. _____. Lower Torso Injuries and Automobile Seat Belts (SAE 760370). SAE Automotive Engineering Congress and Exposition, Detroit (1976).
68. _____. The Rear Seat Automobile Passenger in Frontal Crashes. Proceedings (Vol. 1), 22d AAAM conference (1978).
69. Hurwitt, E.S. and Silver, C.E. Seat belt hernia: a ventral hernia following an automobile crash. JAMA 194:829 (1965).
70. Johannessen, H. George. Historical Perspective on Seat Belt Restraint Systems (SAE 840392). In, Advances in Belt Restraint Systems: Design, Performance and Usage, Detroit (1984).
71. _____ and Pilarski, Regis V. Rear Seat Occupant Protection (SAE 810797).
72. _____ and Vos, Thomas H. The Changing Shape of Seat Belt Systems (SAE 820796).
73. Kahane, Charles. Remarks at meeting sponsored by U.S. Department of Transportation and OECD, The Effectiveness of Safety Belt Use Laws: A Multi-National Examination, Washington, D.C. (1985).
74. Kihlberg, J.K. Efficacy of Seat Belts in Injury and Non-Injury Crashes in Rural Utah. Report VJ-2721-R3, Calspan Corporation, Buffalo (1969).
75. Knoop, J.C. et al. Statistical Evaluation of the Effectiveness of Child Restraints (DOT-HS-805-660), September 1980.
76. Kulowski, J. and Rost, W.B. Intra-abdominal injury from safety belt in auto accident: report of a case. Arch. Surg. 73:970 (1956).
77. Lane, J.M. et al. Evaluation of the 1981-82 Rear Seat Belt Campaign. Road Safety and Traffic Authority (ROSTA) Report No. 4, Victoria (1983).
78. "Lap seat belt useful but can injure children," JAMA 245:2281 (1981). See also, "Lumbar injuries seen as possible result of auto seat belt use," Orthopedics Today 1:1 (1981).
79. Lawson, J.J. and Dalmotas, D.J. An Assessment of the Potential Cost-Effectiveness of a Regulation Requiring Three-Point Rear Seat Belts in Passenger Cars. Proceedings, 3d Canadian Multidisciplinary Highway Safety Conference, London, Ontario (1984).
80. LeMire et al. Intra-abdominal injuries caused by automobile seat belts. JAMA 201:109 (1967).
81. Leung, Y.C. et al. Submarining Injuries of Three-Point Belted Occupants in Frontal Collisions — Description, Mechanisms, and Protection. Proceedings, 26th Stapp Car Crash Conference, Ann Arbor (1982).
82. Levine, Donald N. and Campbell, B.J. Effectiveness of Lap Seat Belts and the Energy-Absorbing Steering System in the Reduction of Injuries. Highway Safety Research Center, University of North Carolina (1971).
83. Lhotka, Donald C. Motor Vehicle Occupant Protection — A Historical Perspective. Proceedings, 19th AAAM conference (1975).
84. Lindgren, S. and Warg, E. Seat belts and accident prevention. Practitioner 188:467 (1962).
85. Lister, R.D. and Milson, B.M. Car seat belts: an analysis of the injuries sustained by car occupants. Practitioner, 191:332 (1963).

86. Louton, J.C. and Ruster, T.W. Restraint Systems, Design and Performance Parameters. Proceedings, GMC Automotive Safety Seminar (1968).
87. Lowne, R. et al. The Effect of the UK Seat Belt Legislation on Restraint Usage by Children. In, Advances in Belt Restraint Systems: Design, Performance and Usage, Detroit (1984).
88. Lundell, B. et al. Safety Performance of a Rear Seat Belt System with Optimized Seat Cushion Design (SAE 810796). SAE Passenger Car Meeting (1981).
89. Mackay, G.M. Belted Occupants in Frontal Crashes. Proceedings, 6th International Conference of the IAATM, Melbourne (1977).
90. _____. Seat Belts in Europe -- Their Use and Performance in Collisions. International Symposium on Occupant Restraint, Toronto (AAAM, 1981).
91. _____. Two Years' Experience with the Seat Belt Law in Britain (SAE 851234).
92. _____ et al. Serious Trauma to Car Occupants Wearing Seat Belts. SAE International Automotive Engineering Congress, Detroit (1973). (Also presented at IRCOBI conference, Birmingham, England, 1975.)
93. MacLeod, J.H. and Nicholson, D.M. Seat belt trauma of the abdomen. Canad. J. Surg. 12:202 (1969).
94. Marsh, Joseph C. et al. Injury Patterns by Restraint Usage in 1973 and 1974 Passenger Cars. Proceedings, 19th Stapp Car Crash Conference, San Diego (1975).
95. McPherson, D. and Oversby, M. Investigations of Injury Mechanisms in Fully Restrained Vehicle Occupants. Proceedings, 6th International Conference of the IAATM, Melbourne (1977).
96. McRoberts, J.R. Seat belt injuries and legal aspects. Industrial Med. Surg. 34:866 (1965).
97. Mellbring, G. et al. The hospital experience of seat belt legislation in the County of Skaraborg, Sweden. Injury 12(6):506 (1981).
98. Mills, P.J. and Hobbs, C.A. The Probability of Injury to Car Occupants in Frontal and Side Impacts (SAE 841652). Proceedings, 18th Stapp Car Crash Conference (1985).
99. Milne, Peter W. Fitting and Wearing of Seat Belts in Australia: The History of a Successful Countermeasure. Australian Dept. of Transport, Office of Road Safety (1979).
100 Moffatt, Charles A. et al. Diagnosis of Seat Belt Usage in Accidents (SAE 840396). In, Advances in Belt Restraint Systems: Design, Performance and Usage, Detroit (1984).
101 Mukerjea, S.K. and Nair, K.K. Seat belt injury causing pneumothorax with rupture of diaphragm, stomach and spleen. Lancet 2:1044 (1978).
102 Najjar, Daniel. Restraint Usage and Effectiveness for Rear Seat Occupants. In, Collected Technical Studies, Vol II: Accident Data Analysis of Occupant Injuries and Crash Characteristics -- Eight Papers, National Center for Statistics and Analysis, U.S. DOT (1981).
103 Nelson, P.G. Aspects of injury patterns in automobile accidents. Aust. N.Z. J. Surg. 47:162 (1977).
104 Newman, James A. et al. Development of a Belt Configuration Test Device (SAE 840402).
105 Niederer, P. et al. Adverse Effects of Seat Belts and Causes of Belt Failures in Severe Car Accidents in Switzerland (SAE 770916). Proceedings, 21st Stapp Car Crash Conference, New York (1977).

106 Norin, Hans and Andersson, Britta. The Adult Belt—A Hazard to the Child? Proceedings, 6th International Association for Automotive and Traffic Medicine (IAATM) International Conference, Melbourne (1977).
107 _____ et al. Children in Cars. (Internal survey performed by Volvo; no date, but not later than 1979).
108 _____ et al. Child Restraints in Cars -- An Approach to Safe Family Transportation (SAE 790320).
109 _____ et al. Seat Belt Usage in Sweden and its Injury Reducing Effect. In, Advances in Belt Restraint Systems: Design, Performance and Usage, Detroit (1984).
110 O'Day, James and Kaplan, Richard. Fatal Injuries to Restrained Passenger Car Occupants. The HSRI Research Review, Vol. 9, No. 1, University of Michigan (1978).
111 O'Neill, Brian. Presentation, SAE Panel on the Political and Technical Considerations of Inflatable Restraints, Detroit (1984).
112 Patrick, L.M. et al. Impact Dynamics of Unrestrained, Lap Belted and Lap and Diagonal Chest Belted Vehicle Occupants (SAE 660788). Proceedings, 10th Stapp Car Crash Conference (1966).
113 Physicians for Automotive Safety. Shoulder belts in rear seats. PAS News (Summer/Fall 1981).
114 Porter, S.E. and Green, E.W. Seat belt injuries. Arch. Surg. 96:242 (1968).
115 Prentice, H.A.J. Seat Belt Effectiveness: Possible Benefits and Advertising. International Symposium on Seat Belts, Tokyo (1979).
116 Preston, Fred. A Comparison of Contacts for Unrestrained and Lap Belted Occupants in Automobile Accidents. Proceedings, 17th AAAM conference, Oklahoma City (1973).
117 Quinn, F.R., Jr. Are seat belts enough? Gen. Pract. 26:101 (1962).
118 Rattenbury, S.J. et al. The Biomechanical Limits of Seat Belt Protection. Proceedings, 23d AAAM conference (1979).
119 Reinfurt, D.W. et al. A Statistical Analysis of Seat Belt Effectiveness in 1973-75 Model Cars Involved in Towaway Crashes. National Highway Traffic Safety Administration, U.S. DOT (1976).
120 Ritchie, W.P., Jr. et al. Combined visceral and vertebral injuries from lap seat belts. Surg. Gynecol. Obstet. 131:431 (1970).
121 Roberts, A.K. The Effects of Rear Seat Passengers on Front Seat Occupants in Front Impacts, TRRL Report LR 1979, Dept. of Transport (UK), London (1983).
122 Roberts, Verne L. et al. Biomechanics of Seat Belt Design. Proceedings, 16th Stapp Car Crash Conference, Detroit (1972).
123 Root, H.D. et al. Peritoneal trauma: experimental and clinical studies. Arch. Surg. 95:531 (1967).
124 Ryan, P. and Ragazzon, R. Abdominal injuries in survivors of road trauma before and since seat belt legislation in Victoria. Aust. N.Z. J. Surg. 49:200 (1979).
125 Scherz, R.G. Fatal motor vehicle accidents of children passengers from birth through 4 years of age in Washington State. Pediatrics, Vol. 68, No. 4 (1981).
126 Schneider, R.C. et al. Lap seat belt injuries: the treatment of the fortunate survivor. Mich. Med. 67:171 (year not legible).
127 Scott, R.E. et al. An Evaluation of the 1974 and 1975 Restraint Systems. Highway Safety Research Institute, University of Michigan (1976).

128 Severy, D.M. et al. Passenger Protection from Front-End Impacts. International Automotive Engineering Congress, Detroit (1969).
129 Sharp, J.E. et al. Analysis of Lap Shoulder Belt Effectiveness in Accidents. Proceedings, 9th Stapp Car Crash Conference (1965).
130 Shortridge, Ray M. A Comparison of Injury Severity Patterns for Unrestrained, Lap Belted, and Torso Restrained Occupants in Automobile Accidents. Proceedings, 17th AAAM conference, Oklahoma City (1973).
131 Smith, W.S. and Kaufer, H. Patterns and mechanisms of lumbar injuries associated with lap seat belts. J. Bone Jt. Surg. 51A:239 (1969).
132 Snyder, R.G. Survey of Automotive Occupant Restraint Systems: Where We've Been, Where We Are, and Our Current Problems (SAE 690243).
133 _____ et al. A new pattern of spine injuries associated with lap type seat belts. U. Mich. Med. Ctr. J. 33 (May-June, 1967).
134 _____ et al. Pathology of trauma attributed to restraint systems in crash impacts. Aerospace Med. 39:812 (1968).
135 _____ et al. Seat Belt Injuries in Impact. Highway Safety Research Institute, University of Michigan (1967).
136 Stapp, Col. John P. and Enfield, Lieut. D.L. Evaluation of the Lap-Type Automobile Safety Belt with Reference to Human Tolerance. Presented at SAE Summer Meeting, Atlantic City (1958).
137 States, J.D. et al. The Medical Aspects of Driver Protection Systems and Devices Developed Through Automobile Racing (SAE 700660).
138 Steckler, R.M. et al. Seat belt trauma to the lumbar spine: an unusual manifestation of the seat belt syndrome. J. Trauma 9:508 (1969).
139 Stevenson, J.H. Severe thoracic, intra-abdominal and vertebral injury occurring in combination in a patient wearing a seat belt. Injury 10: 321 (1979).
140 Straith, C.L. Guest passenger injuries. JAMA 137:348 (1937).
141 Sube, J. et al. Seat belt trauma to the abdomen. Amer. J. Surg. 113:346 (1967).
142 Tarriere, C.H. Proposal for a Protection Criterion as Regards Abdominal Internal Organs. Proceedings, 17th AAAM conference, Oklahoma City (1973).
143 Taylor, T.F.K. et al. Seat belt fractures of the cervical spine. J. Bone Jt. Surg. 58:328 (1976).
144 Thomas, C. et al. The Main Causes of Risk Differences for Restrained Drivers and their Restrained Front Passenger in Frontal Collisions. Proceedings, 9th International Technical Conference on Experimental Safety Vehicles, Kyoto (1982).
145 Tolins, S.H. An unusual injury due to the seat belt. J. Trauma 4:397 (1964).
146 Transport Canada, unpublished data (1985).
147 Trinca, Gordon W. Medical Aspects of Seat Belt Usage. International Symposium on Seat Belts. Tokyo (1979).
148 _____. the Medical Significance of Occupant Restraint on Road Crash Victims and Those Who Treat Them. International Symposium on Occupant Restraint. Toronto (AAAM, 1981).
149 U.S. Department of Transportation. Denial of Petition for Rulemaking (49 F.R. 15241, April 18, 1984).
150 _____. Docket No. 74-14; Notice 17 (44 F.R. 77210, December 31, 1979).
151 _____. Docket No. 74-14 (44 F.R. 2060, December 1980).

152 _____. Docket No. 74-14; Notice 19 (46 F.R. 2064, January 8, 1981).
153 _____. Docket No. 74-14; Notice 37 (50 F.R. 14580, April 12, 1985).
154 _____. Docket No. 74-14; Notice 38 (50 F.R. 14589, April 12, 1985).
155 _____. Docket No. 74-14; Notice 39 (50 F.R. 14602, April 12, 1985).
156 _____. Docket No. 74-14 (50 F.R. 34152, August 23, 1985).
157 _____. Docket No. 74-14; Notice 42 (50 F.R. 46056, November 6, 1985).
158 _____. Final Regulatory Impact Analysis of the amendment to FMVSS 208: Passenger Car Front Seat Occupant Protection, July 11, 1984.
159 Vellar, I.D. et al. Rupture of the bowel due to road trauma: the emergence of the seat belt syndrome. Med. J. Aust. 1:694 (1976).
160 Volvo Car Corporation and Swedish Road Safety Office. Injury-Reducing Effect of Seatbelts on Rear Seat Passengers (1979).
161 Wagenaar, Alex. Remarks at meeting sponsored by U.S. DOT and the OECD, The Effectiveness of Safety Belt Use Laws: A Multi-National Examination. Washington, D.C. (1985).
162 Walpole, Bryan. Motor vehicle accident — multiple trauma. Australian Family Physician, Vol. 13, No. 4, (1984).
163 Walz, Felix H. et al. Severely and Fatally Injured Rear Seat Car Passengers (OAIS >/= 2) in Switzerland During 1976. Proceedings, 22d AAAM conference (1978).
164 Warner, Charles Y. Belt Occupant Restraint Effectiveness. Proceedings, 17th AAAM conference, Oklahoma City (1973).
165 Wexler, L. and Silverman, J. Traumatic rupture of the innominate artery — a seat belt injury. N. Eng. J. Med. 21:1186 (1970).
166 Wild, B.R. et al. Effect of seat belts on injuries to front and rear seat passengers. Br. Med. J. 290:1621 (1985).
167 Williams, Allan F. and Zador, Paul. Injuries to children in automobiles in relation to seating location and restraint use. Accident Analysis and Prevention, Vol. 9, No. 1 (1977).
168 _____ et al. Occupant Protection in Interior Impacts: An Analysis of FMVSS No. 201. Proceedings, 23d AAAM, Louisville (1979).
169 Williams, James S. and Kirkpatrick, John R. The nature of seat belt injuries. J. Trauma 11:207 (1971). (Also published as SAE 700896 in, Proceedings, 14th Stapp Car Crash Conference, Detroit (1970); also presented at 28th Annual Convention of the American Association for Surgery of Trauma, Montreal (1971).
170 _____ et al. The automotive safety belt: in saving a life may produce intra-abdominal injuries. J. Trauma 6:303 (1966).
171 Witte, C.L. Mesentery and bowel injury from automotive seat belts. Ann. Surg. 167:486 (1968).
172 Woelfel, G.F. et al. Severe Thoracic and Abdominal Injuries Associated with Lap-Harness Seatbelts. J. Trauma, Vol. 24, No. 2 (1984).
173 Yajko, R.D. et al. Rupture of the stomach from blunt abdominal trauma. J. Trauma 15:177 (1975).

APPENDIX A

SUMMARIES OF SAFETY BOARD CRASH INVESTIGATIONS IN LAP BELT PERFORMANCE STUDY

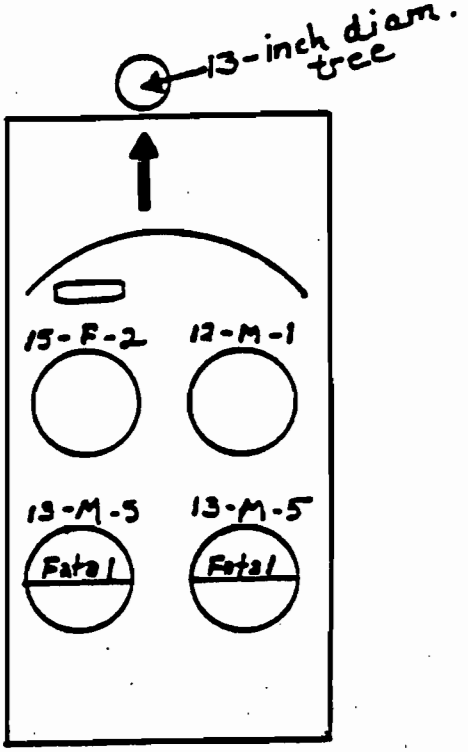
The following case summaries present detailed information on each case. On the first page of each summary there is a sketch of the crash configuration, showing the case vehicle and whatever object it struck (or was struck by). Each occupant is shown by a circle drawn at the occupant's seating location. The type of restraint used by that occupant is indicated also: two lines drawn across the circle indicate a 3-point lap shoulder belt, one line indicates a lap-only belt. If the occupant was killed, the word "fatal" is across, or near, the circle. Each occupant's age, sex, and highest AIS injury level is indicated on or near each circle. For example, 3-M-5 would indicate a 3-year-old boy who received an AIS 5 level injury as his most severe injury; 37-F-1 would indicate a 37-year-old woman whose most severe injury was AIS 1.

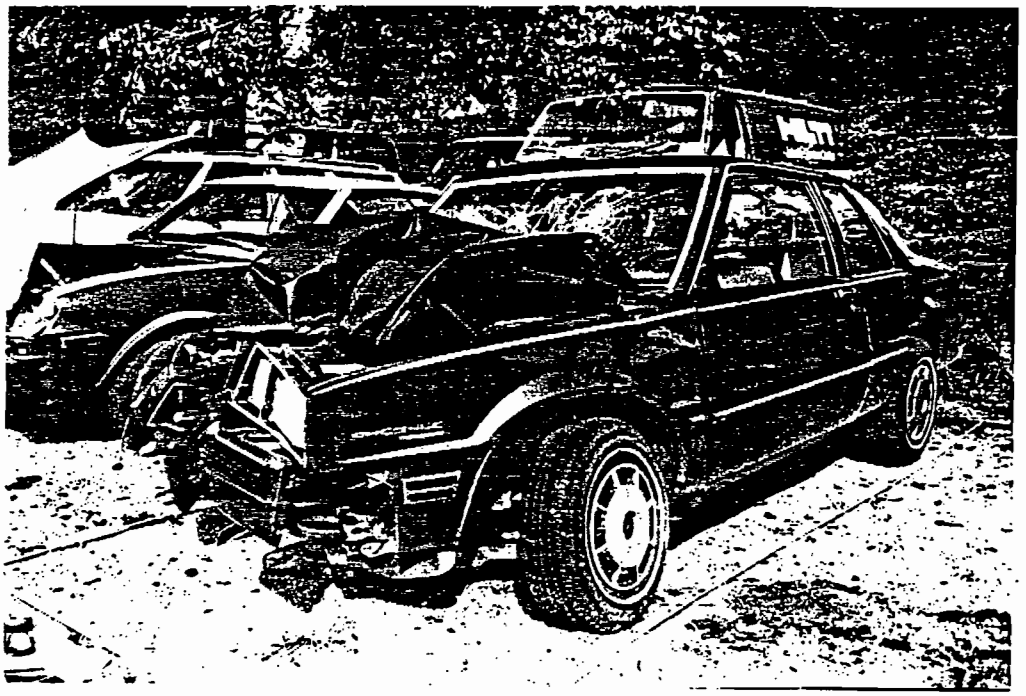
A photograph of the case vehicle is also provided. It should be noted that a substantial amount of crush in the front area of a passenger car does not necessarily denote severe crash forces. There is a considerable difference in the "stiffness" of various motor vehicle designs; if a "stiff" vehicle sustains substantial deformation, that would suggest larger crash forces than the same degree of deformation in a less "stiff" vehicle. It is also important to focus attention on the condition of the passenger compartment, for evidence of intrusion.

There is a glossary in appendix D and anatomical drawings in appendix G for assistance in understanding unfamiliar types of injuries or parts of the body.

CASE 1 (CHI-84-H-OR23)

Case vehicle: 1983 Pontiac Phoenix
Case vehicle weight: 2,893 pounds
Case vehicle Delta V: 37.1 mph





Circumstances

A 1983 Pontiac Phoenix struck a 13-inch-diameter tree head-on. The impact destroyed the front structure of the vehicle, with rearward structural collapse of up to 39 inches at the approximate center front. The car was driven by a 15-year-old girl and occupied by a 12-year-old boy in the right front seat, a 13-year-old boy in the left rear seat, and a 13-year-old boy in the right rear seat. The boys in the rear seat were wearing lap belts; the driver and right front passenger were unrestrained.

The accident resulted in moderate injuries to the unrestrained driver and minor injuries to the unrestrained right front passenger. The lap belted left rear passenger sustained massive abdominal injuries and was found to be without vital signs upon arrival at a hospital. All attempts to revive this boy failed, and he was pronounced dead approximately 48 minutes after the crash. Paramedics responding to the accident found that the lap belted right rear passenger had no blood pressure. This boy arrived at a hospital 1 hour after the crash. He was in cardiac arrest and without vital signs. Initial attempts to restore vital signs were successful but repeated tests made from the time of admission to the hospital over a period of several days failed to show any brain activity. He was pronounced dead 5 days after the crash.

Restraint and Injury

Seating location: Driver
Sex: F
Age: 15
Height: 4 feet 10 inches
Weight: 92
Seated height: 28 inches
Restraint used: None
Proper use? NA

Although a 3-point, continuous loop, lap/shoulder belt was provided at the driver's seat position, it was not in use at the time of this crash. The entire steering assembly in front of this occupant was displaced forward, with the wheel rim severely deformed.

Injuries	AIS	Probable Source
Partial avulsion of upper teeth	1	Steering wheel rim
Fractured anterior maxilla	2	Steering wheel rim
Laceration (5-6 cm), anterior maxilla gingiva	1	Steering wheel rim
Laceration (4 cm), upper lip	1	Steering wheel rim
Grade 1 strain, lateral collateral ligaments, left knee	2	Lower instrument panel
Contusion, left knee	1	Lower instrument panel
Strain, left ankle	1	Below instrument panel
Strain, right ankle	1	Below instrument panel
Laceration, right front scalp	1	Windshield
Contusion, left upper arm	1	Steering wheel rim
Abrasion, right knee	1	Lower instrument panel
Abrasion, left knee	1	Lower instrument panel
Abrasion, outer right thigh	1	Unknown

This occupant was admitted to the hospital for an unspecified period.

Seating location: Right front
Sex: M
Age: 12
Height: 5 feet 2 inches
Weight: 105
Seated height: 28 inches
Restraint used: None
Proper use? NA

This boy said he was wearing the 3-point lap/shoulder belt furnished at his seat position, with both the lap belt and shoulder strap adjusted "very loosely." However, Safety Board investigators could find no corroborating evidence of belt use, however loosely adjusted. A comparison of injury locations to known and most probable contact points shows that this boy could not have been permitted sufficient forward travel within the restraint system for these to have occurred. In such a collision, it would be expected that well-defined loading marks from both the cinching type of latchplate and the D-ring would occur. An abrasion caused by the shoulder strap would also be expected with an adjustment such as this boy described. In sum, the Board does not believe that this occupant was restrained at the time of the crash.

The instrument panel forward of this boy was displaced rearward several inches and appeared to be depressed inward at its lower center. The windshield was also broken outward, with "spiderweb" effect, in front of this boy's seat position.

Injuries	AIS	Probable Source
Scratches across forehead	1	Windshield
Contusions, right inner thigh	1	Unknown
Laceration, anterior lower left leg	1	Lower instrument panel
Lacerations, lower left junction of ribs with abdomen	1	Instrument panel
Contusion, left hip	1	Lower instrument panel

These injuries were described by the victim; he did not seek medical attention.

Seating location: Left rear
Sex: M
Age: 13
Height: 4 feet 11 inches
Weight: 106
Restraint used: Lap belt (ALR)
Proper use? Probably, with possible submarining

This boy was restrained by a lap belt with an automatic locking retractor (ALR), a sewn-in type of latchplate, and a pushbutton release type of buckle. The right front passenger said this boy's belt was positioned across the stomach and that the boy was "slouched" forward in his seat. The hospital records indicate that abrasions and contusions were across his lower abdomen, but do not define "lower abdomen" well enough for a proper evaluation. The Safety Board believes it is entirely possible the belt was in proper position before the crash, lying over the iliac crest, but that the foam lower seat cushion was compressed sufficiently downward and forward during the crash to allow a

submarining action. This was probably great enough to allow body travel under the belt, resulting in the belt rising above the iliac crest and causing the apparent massive internal injuries. Had the belt initially been adjusted too high, over the top of the iliac crest, it is very likely that the boy's internal injuries would have been to major organs located higher in the abdominal cavity and that the medical record would reflect a much higher location of the abdominal abrasions and contusions. This would especially be true if major submarining did indeed occur. (This analysis is based on an assumption that the left rear occupant received the same type of internal injuries as those of the right rear occupant. This assumption appears reasonably valid, since both occupants displayed the same area of abrasions and contusions, along with similarly distended abdomens noted by the hospital, and because both were subjected to the same collision forces.)

There were no contact points noted in the investigation other than feet contact with the lower rear framework of the driver's seat.

Injuries	AIS	Probable Source
Large abrasion across lower abdomen with ecchymosis	2	Lap belt
Massive internal injuries	7	Lap belt
Contusions, left upper chest	1	Contact with legs (or CPR)
Level of consciousness	5	Internal bleeding due to lap belt

This occupant was never revived after the crash. He was pronounced dead 48 minutes after the accident. Hospital officials noted that abdominal abrasions due to the lap belt were present. A note on the hospital records also indicated a distended abdomen. No autopsy was performed, but the coroner attributed death to "massive internal injuries from a seat belt which was thought to be fastened too high across the abdomen, or too loose, in which, upon impact, the belt raised up across the victim's abdomen, transmitting all the impact force to a confined area across the victim's abdomen approximately midway between his navel and the pubic area." (But see discussion above concerning probable fit.) No evidence of head injury was found.

Seating location: Right rear
Sex: M
Age: 13
Height: 5 feet
Weight: 90
Restraint used: Lap belt (ALR)
Proper use? Probably

This occupant was restrained by a lap belt similar to the one used by the left rear passenger. The right front passenger said the right rear passenger had his belt loosely "about his waist or legs" and that he was leaning forward onto the rear surface of the front seat cushion. Postcrash witnesses found him bent forward with his head between his knees. The medical records report contusions and abrasions about the lower abdomen and hip. The only occupant contact points noted in the Safety Board investigation were feet contact with the lower framework of the front seat.

This occupant was revived from complete cardiac arrest and kept on life support systems for 5 days. At admission to the hospital, he was noted to have a distended abdomen. His abdominal injuries were identified as lap belt related. Surgical records indicated an unspecified amount of blood found in the abdominal cavity. The coroner's report noted that the victim apparently bled severely into the abdominal cavity, resulting in brain death due to lack of blood in the brain. While the cause of death did not specifically mention the lap belt, the fatal injuries were described by medical records as being caused by the lap belt.

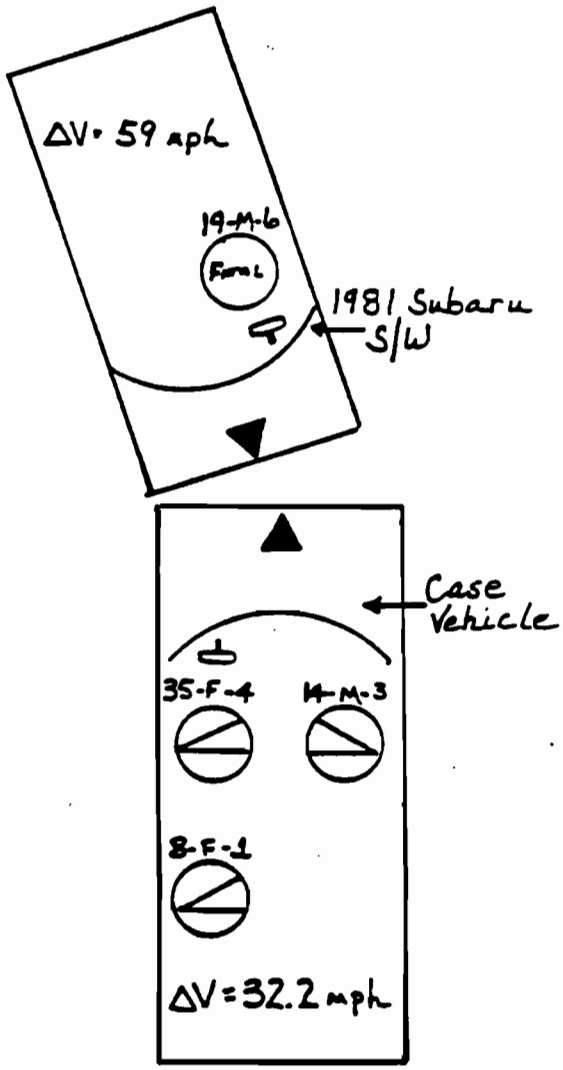
Taking all the facts into account, the Safety Board believes this boy was probably wearing the lap belt within the zone considered proper fit. Even if he had been leaning forward before the crash, this posture would not contribute to improper belt adjustment.

Injuries	AIS	Probable Source
Contusion with hematoma, lower abdomen	2	Lap belt
Small bowel totally detached from its mesentery	4	Lap belt
Deserosalization, small bowel (several areas of 1 to 1 1/2 inches)	7	Lap belt
Deserosalization, sigmoid colon	7	Lap belt
Torn mesentery of small bowel (1 to 2 feet of devascularization)	4	Lap belt
Abrasions, lower abdomen	2	Lap belt
Abrasions, hip	1	Lap belt
Level of consciousness	5	Internal bleeding due to lap belt

Compare the external injury notations for both rear, lap belted occupants (both boys of about the same height and weight): both had abdominal contusions and abrasions in the same location, both had the same distended abdomen, and both suffered brain death due to lack of sufficient blood for supplying oxygen to the brain. In short, they underwent the same impact forces, had the same external evidence of injury, and both died of the same cause. The available information seems to indicate that both fatally injured rear seat passengers were wearing the lap belt restraints properly prior to the crash.

CASE 2 (FTW-84-H-OR16)

Case vehicle: 1982 Jaguar XJ-6, 4-door
Case vehicle weight: 4,350 pounds
Case vehicle Delta V: 32.2 mph



Circumstances

A 1982 Jaguar was struck in the left front by a 1981 Subaru stationwagon, approximately 18 degrees from direct head-on. The impact forces completely destroyed the frontal structures of both cars. The Jaguar was driven by a 35-year-old woman and occupied by her 14-year-old son, seated right front, along with her 8-year-old daughter, seated left rear. All of the Jaguar occupants were wearing 3-point, continuous loop, lap/shoulder belts.

This accident resulted in fatal injuries to the 19-year-old unrestrained driver of the Subaru. The driver of the Jaguar sustained serious injuries due to the rearward collapse of the frontal compartment at her seating position. Moderate injuries resulted to the Jaguar right front passenger, while the left rear passenger sustained only minor abrasions, attributed to the restraint webbing.

Restraint and Injury

Seating location: Driver
Sex: F
Age: 35
Height: 5 feet 2 inches
Weight: 100
Restraint used: Lap/shoulder belt (ELR)
Proper use? Yes

This driver was wearing a 3-point, continuous loop, lap/shoulder belt with an emergency locking retractor (ELR), a free-sliding latchplate, and a pushbutton release type of buckle mounted to a flexible stalk. The seat was adjusted to its forwardmost position on an 8-inch track, secure at its attachments and without permanent deformation. The belt webbing was cut during rescue and extrication efforts. A force loading scar was found on the system webbing, beginning at 59 inches above the lower outboard anchor and extending for 2 7/8 inches. The plastic housing of the stalk-mounted buckle was shattered, with the latchplate torque still inserted and secure.

The frontal area of the driver's compartment was displaced rearward several inches due to the impact forces, resulting in a compression of the space between the seatback cushion and steering assembly, from 21 inches down to 13 inches. The instrument panel was displaced rearward a total of 13 1/2 inches at its left outboard side, and the left side A pillar was 12 inches rearward of its original position. The vehicle's floorpan, along with foot controls, was deformed rearward with the collapsing structure.

The Jaguar driver was subjected to severe impact forces, acting in a direct line through her seating position. With the crash induced frontal interior collapse at this position, there was no available space for a safe ride-down. The interior actually collapsed rearward into the driver, rather than the driver traveling forward a great distance. The underdash components and foot controls were pushed rearward and inboard, producing severe injuries to the occupant's lower extremities.

Injuries	AIS	Probable Source
Laceration, inside lower lip	1	Steering wheel rim
Contusion, lower front face	2	Steering wheel rim
Contusions, lower right neck	2	Steering wheel rim
Concussion	4	Forces from impact with steering assembly
Fractured femur, right side	3	Lower instrument panel
Laceration into right knee joint	2	Lower instrument panel
Contusion, left knee	1	Lower instrument panel
Fractured right ankle	2	Floorpan and foot controls
Fractured toes, left foot	2	Floorpan and foot controls
Contusions, lower abdominal area	2	Lap belt
Multiple contusions, upper torso	2	Shoulder strap and steering assembly

This driver required hospitalization for 19 days. The recovery period was longer than 6 months.

Seating location: Right front
Sex: M
Age: 14
Height: 5 feet 4 inches
Weight: 125
Restraint used: Lap/shoulder belt (ELR)
Proper use? Yes

This passenger was wearing a 3-point, continuous loop, lap/shoulder belt with an ELR, a free-sliding latchplate, and a pushbutton release type of buckle mounted to a flexible stalk. There was a circular area of damage in the front and upper surface of the instrument panel, located several inches inboard of the longitudinal centerline of this seating position. Further inspection revealed a force loading scar on the belt webbing, beginning at 61 inches from the lower outboard anchor and extending for 2 1/2 to 2 3/4 inches. The bucket seat was adjusted to its forwardmost limit on an 8-inch track. The front portion of the lower seat cushion was compressed from an original 21-inch width down to 16 inches, due to rearward and right outboard distortion of the center console structure. The precrash seatback position was not determined, due to post crash and extrication alteration of adjustment. The seat assembly's attachment to the lower right rear track was displaced approximately 2 inches upward and forward. The right front passenger, absorbing an angular force line, was propelled forward into head contact with the dashboard. Had no restraint been used, a severe head impact into the windshield would have occurred. There also would have been a possibility of ejection through the windshield.

Injuries	AIS	Probable Source
Major contusion, nose and left face	2	Instrument panel
Nose fracture	1	Instrument panel
Fractured cheekbone	2	Instrument panel
Major contusion, lower abdomen	2	Lap belt
Contusion, bladder	3	Lap belt
Contusion, lower right neck	1	Shoulder strap
Contusion, shoulder	1	Shoulder strap

This boy required 4 days of hospital treatment and missed 4 more days of school.

Seating location: Left rear
Sex: F
Age: 8
Height: 4 feet 2 inches
Weight: 45
Restraint used: Lap/shoulder belt (ELR)
Proper use? Yes

This passenger was restrained by a 3-point, continuous loop, lap/shoulder belt with an ELR mounted on the rear parcel deck, a free-sliding latchplate, and a pushbutton release type of buckle attached to a short length of webbing. An examination of the webbing revealed a 2-inch scar, beginning 51 inches above the lower outboard anchor. There was no significant deformation of the interior compartment at this seating position other than a 2-inch forward displacement of the extreme upper left outboard seatback cushion.

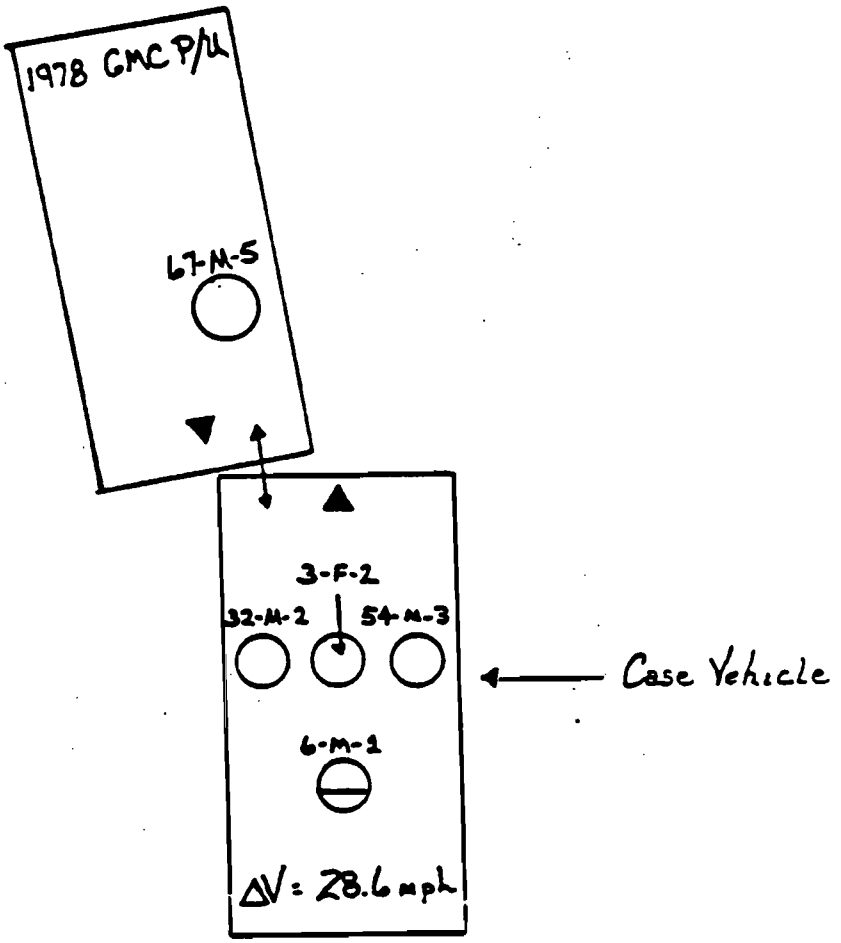
Injuries	AIS	Probable Source
Contusion, left side of neck	1	Shoulder strap
Lower abdominal contusions	1	Lap belt

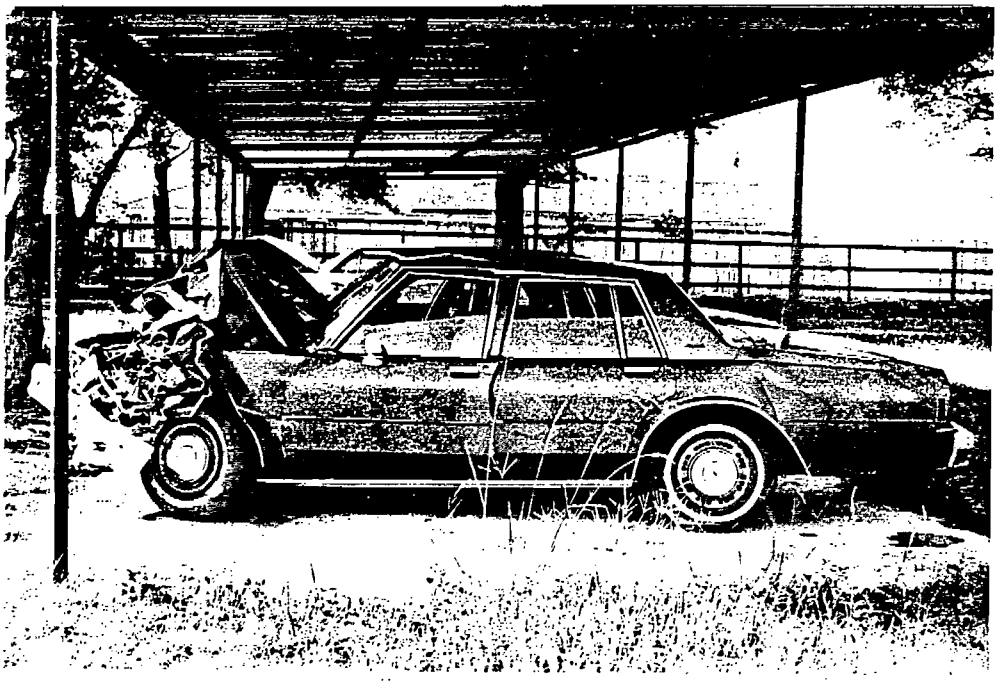
This passenger was treated and released. There was no loss of school attendance reported.

A comparison can be made between the success of this left rear occupant's full restraint and cases involving similar dynamics with only a lap belt used. These comparisons suggest that this occupant would have suffered some level of pelvic or abdominal injuries if she had been restrained by a lap belt only. The severity of those injuries would be open to speculation. Consider Case 13, in which two small children rode down a crash of Delta V 29 mph with only minor injuries, while restrained by lap belts only. One factor which could have influenced the severity of the Jaguar left rear passenger's injuries, had she been wearing a lap belt only, is her additional height over that of the smaller occupants of Case 13. This extra height would have placed her head and neck forward of her upper legs and knees, should she have jackknifed over a lap belt. This condition would certainly have increased the probability of severe cervical injury due to hyperflexion.

CASE 3 (FTW-84-H-OR17)

Case vehicle: 1984 Chevrolet Impala, 4-door
Case vehicle weight: 4,000 pounds
Case vehicle Delta V: 28.6 mph





Circumstances

A 1984 Chevrolet Impala was struck virtually head-on, left front to left front, by a 1978 GMC pickup. The Impala was occupied by a 32-year-old unrestrained male driver, an unrestrained 3-year-old girl seated center front, a 54-year-old man riding unrestrained at the right front, and a 6-year-old boy riding center rear restrained by a static lap belt. The force of the collision halted the Impala's forward travel and pushed it backward several feet. The front structures of both vehicles were destroyed by the severe collision forces.

This accident resulted in serious injuries to the unrestrained front seat occupants of the Impala. The lap belted 6-year-old rear seat passenger received minor abdominal contusions and minor facial lacerations and abrasions. The unrestrained 67-year-old driver of the pickup reportedly sustained critical (AIS 5) injuries.

Restraint and Injury

Seating location: Driver
Sex: M
Age: 32
Height: 6 feet
Weight: 170
Restraint used: None
Proper use? NA

This driver was not wearing the available 3-point lap/shoulder belt. The instrument panel in front of him was displaced rearward up to 2 inches. The steering assembly was deformed downward, with the wheel rim bent forward approximately 10 inches along its top circumference. Windshield damage with a "spider web" pattern was found forward of and slightly inboard of the seating position.

Injuries	AIS	Probable Source
Large abrasion, left forehead	2	Windshield
Large abrasion/contusion, right upper quadrant of abdomen	2	Steering assembly
Large abrasion/contusion, abdominal wall at the umbilical area	2	Steering assembly
Contusion, right thigh	1	Steering assembly
Abrasion, right knee	1	Instrument panel
Abrasion, left knee	1	Instrument panel
Major abrasion, right forearm	2	Instrument panel
Lacerations, right hand	1	Instrument panel
Lacerations, left hand	1	Instrument panel

The man spent 3 days at a hospital and missed several days of work due to his injuries and treatment.

With the available clear space forward of the driver, observed postcrash, it can reasonably be suggested that his injuries would have been substantially less if he had used the lap/shoulder belt, properly adjusted.

Seating location: Center front
Sex: F
Age: 3
Height: 38 inches
Weight: 33
Restraint used: None
Proper use? NA

This child was not wearing the available static lap belt. The center of the instrument panel was displaced rearward approximately 1 inch; the panel surface was severely distorted, due to buckling and crushing of the components. A two-way radio control head was mounted below the instrument panel, directly over the transmission tunnel.

Injuries	AIS	Probable Source
Major contusion, forehead	2	Instrument panel
Avulsion, three primary incisors	1	Instrument panel
Laceration of tongue	2	Instrument panel
Abrasion, chin	1	Instrument panel
Fracture, left tibia	2	Instrument panel
Fracture, left fibula (displaced)	3	Instrument panel
Major contusion, left forearm	2	Instrument panel
Abrasion, right knee	1	Instrument panel
Laceration, lower right leg	1	Instrument panel
Contusions, posterior right thigh	1	Instrument panel

The girl was hospitalized for 3 days. Although hospital records state she was ejected from the vehicle, this was not so.

It is instructive to compare this unrestrained child's injuries with those sustained by a child of similar size seated in the same position, in a car of similar size and loaded weight, involved in a frontal collision of almost identical Delta V, this latter child wearing a static lap belt (see Case 13). Such a comparison suggests that if the child in this case had been lap belted, she might have sustained severe head injuries, although many of her actual minor to moderate injuries probably would have been prevented.

Seating location: Right front
Sex: M
Age: 54
Height: 6 feet 2 inches
Weight: 220
Restraint used: None
Proper use? NA

This man was not wearing the available 3-point lap/shoulder belt. The instrument panel was displaced rearward by approximately 1 inch, with the panel surface badly broken and distorted. An area of windshield damage was also noted forward of and slightly outboard of this seat position.

Injuries	AIS	Probable Source
Small laceration, left medial eyebrow	1	Windshield
Small laceration, bridge of nose	1	Windshield
Contusion, left eye	2	Windshield
Contusion, chin	1	Windshield
Comminuted fracture and dislocation of left hip	3	Instrument panel
Abrasion/contusion, left knee	1	Instrument panel
Laceration, lower right leg	1	Instrument panel
Laceration, lower left leg	1	Instrument panel
Laceration, right hand	1	Instrument panel
Laceration, left hand	1	Instrument panel
Laceration, superior right shoulder	1	Instrument panel
Small (1/2 cm) laceration, tongue	1	Windshield

He was transferred to a second hospital 5 days after the crash and spent several weeks in treatment and rehabilitation.

This position had the greatest postcrash clear space available forward of the occupant. A properly worn, properly adjusted lap/shoulder belt would have prevented the major injury-causing contacts.

Seating location: Center rear
Sex: M
Age: 6
Height: 4 feet 3 inches
Weight: 50
Restraint used: Lap belt (static)
Proper use? No

This boy was wearing the static lap belt provided at his center rear seat position. He apparently was riding with a plastic tackle box resting on his lap. The rear surface of the front seatback in front of him was deformed forward 9 inches at its uppermost surface and 5 inches at its lower surface. The seatback deformation was approximately centered along the cushion width, directly behind a fold-down center armrest for the front seat. Sharp indented scars, 12 inches in width, were found in the seatback fabric, 8 to 13 inches below the uppermost surface. These indentations matched the exterior dimensions of the plastic tackle box. Shards of the plastic box were found on the rear compartment floor and the rear seat cushion.

The static lap belt at this position had a sewn-in, pushbutton release type of buckle attached to a length of webbing which extended 6 1/2 inches from the seat cushion junction. An adjustable position, cinching type of latchplate was attached to a 36-inch portion of webbing, which also came out from between the seat cushions. A 14-inch lateral separation was measured between the webbing entry points. A webbing scar from force loading was found at 14 to 16 1/2 inches from the latchplate webbing's entry point between the cushions. The latchplate was found, jammed by a folded-over portion of webbing, at 14 inches from the entry point.

As the collision forces acted, the plastic box was between the child and the rear surface of the front seat. The box, weighing an estimated 10 to 14 pounds, struck the seatback with enough force to shatter the box and severely deform the seat structure. The facial cuts and abrasions received by the boy were probably the result of contact with the box. An inspection of the vehicle interior surrounding this seating position revealed no other surfaces that might have produced such injuries.

The lap belt probably was not adjusted to a snug fit. The load mark location found on the webbing does not seem consistent with proper adjustment to the body size of the occupant. The 2 1/2 inches of webbing travel through the latchplate was not excessive when the Delta V is considered. However, the latchplate did not lock properly. The point of lockup was on a folded-over portion of the webbing. There was a retarding effect on the webbing, shown by the load mark, leading up to the folded-over area within the latchplate locking bar, but it is not known how much latchplate travel would have been allowed over normal (unfolded) webbing. It appears possible that without the webbing fold, the webbing might have continued to slip through the latchplate.

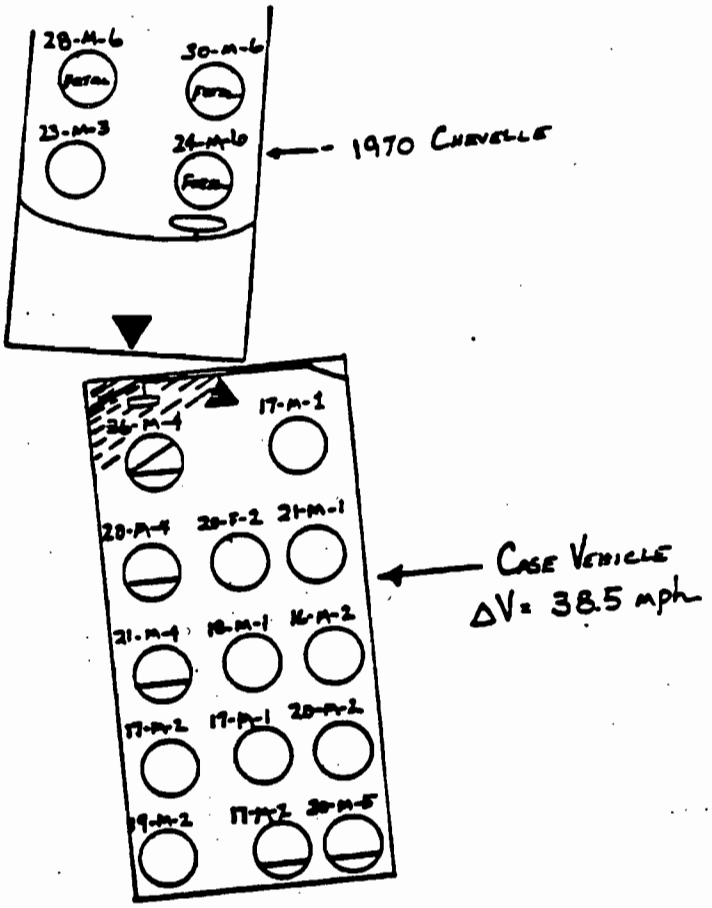
The Safety Board believes the performance of the center rear lap belt in this case was probably affected by three factors: 1) the loose belt adjustment, 2) the distance of webbing travel allowed through the cinching type of latchplate, and 3) the energy-absorbing effect of the plastic tackle box between the occupant and his possible contact points. These factors allowed the child to ride down the severe impact forces without serious head, spine, or abdominal injuries. As the child began to reach the limits of travel within the loosely adjusted restraint webbing, the plastic box began to absorb and help dissipate the forces. Had the webbing system been "snugged up" and had the latchplate not allowed several inches of webbing travel through its cinching bar, this child would have been decelerated from high speed, in a very brief time period, by a 2-inch-wide piece of webbing in the abdominal area. It can reasonably be expected that serious internal injuries might have occurred had the system been adjusted properly and functioned properly, given the forces involved in this collision.

Injuries	AIS	Probable Source
Laceration (1 cm), under left eye	1	Tackle box
Small laceration, below right side of nose	1	Tackle box
Contusion, gums	1	Tackle box
Abrasion, chin	1	Tackle box
Abrasions, scattered over chest	1	Tackle box
Contusions, abdomen	1	Lap belt

The boy was treated and released at a hospital and attended school on the day following the accident.

CASE 4 (SEA-84-H-OR06)

Case vehicle: 1983 Dodge Maxi-Wagon (15-passenger van)
Case vehicle weight: 7,410 lbs.
Case vehicle Delta V: 38.5 mph



Circumstances

A 1983 Dodge 15-passenger van was struck head-on by a 1970 Chevrolet Chevelle. The van was being driven by a 36-year-old man restrained by a lap/shoulder belt. There were 13 other occupants in the van, 4 of whom were restrained by static lap belts at various seating positions, 9 of whom were unrestrained.

The collision destroyed the front structure of both vehicles. Three of the four unrestrained Chevrolet occupants received fatal head injuries. The remaining Chevrolet occupant, seated right front, sustained serious to critical head injuries and multiple fractures.

The collision caused serious to critical injuries to all belted occupants of the van, most of them lap belt induced. The unbelted occupants sustained only minor to moderate injuries.

This case should be compared to Case 23, also involving a van but occupied by lap belted and unrestrained small children, with similar results.

Restraint and Injury

Seating location: Driver
Sex: M
Age: 36
Height: 5 feet 10 1/2 inches
Weight: 160
Restraint used: Lap/shoulder belt (ELR)
Proper use? Yes

This man was restrained by a 3-point, continuous loop, lap/shoulder belt with an ELR, a cinching type of latchplate, and a pushbutton release type of buckle rigidly mounted to the base of the bucket seat. A "windowshade" type of tension relief device was also incorporated into the system. The Safety Board investigation did not document loading scars on the belt webbing, due to the compartmental damage and the inaccessibility of system components. For the same reasons, no determination of seat track adjustment could be made.

There was massive rearward deformation of the frontal area at this position. The collapsing front structure of the van resulted in this occupant being trapped in his seating area for 2 hours. The steering assembly showed severe rearward and upward displacement; some of the upward displacement was due to extrication efforts.

This driver related that, prior to the crash, his lap belt was positioned low on his hips with "snug" tension. He said that the shoulder strap crossed over his mid-sternum, but he could not describe webbing tension. The restraint webbing at this position was cut by rescue workers.

Injuries	AIS	Probable Source
Fracture, anterior cranial fossa floor	4	Steering assembly
Fracture, frontal maxillary	2	Steering assembly
Complex fracture, right zygomatic	2	Steering assembly
Fracture, intraorbital rim	2	Steering assembly
Fracture, 2nd left molar	1	Steering assembly
Scalp laceration (victim stated 3 inches)	2	Steering assembly
Comminuted fracture, right patella	3	Lower instrument panel and below
Comminuted fracture, left tibia	3	Lower instrument panel and below
Comminuted fracture, left fibula	3	Lower instrument panel
Dislocation and fracture, right foot metatarsals	2	Lower instrument panel and below
Open lacerations, right leg tibia	2	Lower instrument panel and below
Abrasion, right side, top of iliac crest	1	Lap belt
Contusion, upper left chest	1	Shoulder strap and/or steering rim

He spent 13 days in two hospitals, and an extended period of outpatient care was required following his initial hospital release. As of 7 months after the crash, he was still unable to return to work.

The restraint system performed much better than could be expected in a crash of this severity. The nature of a van's frontal structure is such that, in an offset frontal collision, there is little survivable space left in line with the rearward collapse. An unrestrained occupant seated behind this collapsing structure is normally decelerated by a combination of jagged metal, broken plastic, and windshield glass. With the steering control gearbox located under the extreme left front, an impact such as the one in this case forces the steering assembly rearward and upward very quickly. In fact, the steering wheel rim in this case probably had already reached the level of the driver's face just as he reached the limits of restraint provided by his shoulder strap. If this speculation is accurate, an unrestrained driver, given the same crash circumstances, would have had his head travel stopped instantaneously, while his torso continued moving forward several inches. This probably would have resulted in fatal cervical injuries, at a minimum.

Thus, the lap/shoulder belt worn by this driver was instrumental in preventing fatal injuries. Given the crash force line and severity, an unrestrained driver would have been fatally injured.

Seating location: Right front
Sex: M
Age: 17
Height: 5 feet 10 inches
Weight: 135
Restraint used: None
Proper use? NA

This man was not wearing the available 3-point lap/shoulder belt. There was moderate rearward distortion of the lower inboard frontal compartment at this position. Additionally, the vehicle's windshield was displaced out of its framework. This occupant and other witnesses said that he was partially ejected through the windshield space.

Injuries	AIS	Probable Source
Laceration (3 stitches), right side of face	1	Front exterior of van
Laceration (1 stitch), right elbow	1	B pillar area
Laceration (3 stitches), right lower arm	1	B pillar area
Lacerations, lower right leg	1	Below instrument panel
Lacerations, lower left leg	1	Below instrument panel
Contusion, right lower hip and upper thigh	1	Instrument panel and sidewall
Contusion, right knee	1	Instrument panel and below

He was treated and released at a hospital. He related that out-patient care was required following release and that he lost 1 month of work as a result of the accident injuries.

The missing windshield allowed deceleration with the occupant's upper body bowing over the padded dashboard forward of his seat. If the windshield had not been displaced, this occupant's head would have struck the glass, probably followed by a severe rearward flexion of his neck. Furthermore, it should be noted that the friendly deceleration undergone by this occupant is an exception rather than a rule. The smooth, rounded surface into which he decelerated could be compared to that provided by a child restraint device such as the Ford "Tot Guard," which incorporates a large, rounded shield in front of the child.

Seating location: Bench 1, extreme left
Sex: M
Age: 20
Height: 6 feet 2 inches
Weight: 155
Restraint used: Lap belt (static)
Proper use? Yes

This man was restrained by a static lap belt that incorporated a cinching type of latchplate, adjustable in position on a 49-inch webbing, and a pushbutton release type of buckle attached to a 9-inch length of webbing. Both buckle and latchplate webbing were attached to the seat framework approximately 4 inches behind the junction of the upper

and lower seat cushions. The tubular lower seat support posts were bent forward 4 inches directly below this position. The seatback cushion was deformed forward several inches, with an overall bow of 4 1/2 inches in the 1-inch tubular frame concealed by upholstery just under the top of the cushion.

The seatback of the van driver, directly forward of this occupant, was removed by rescue personnel and was not available for the Safety Board investigation. Consequently, no documentation of this occupant's forward area could be made.

This man related that his lap belt was routed low on his hips and that the tension was "snug." He said he was wearing a heavy coat under the belt.

Injuries	AIS	Probable Source
Basilar skull fracture	3	Driver's seatback
Ruptured right tympanic membrane	2	Driver's seatback
Fractured right mandible-unspecified	1	Driver's seatback
Dislocation, teeth	1	Driver's seatback
Transverse process fracture, L2	2	Lap belt
Transverse body fracture, L4	3	Lap belt
Comminuted fracture, right iliac crest	3	Lap belt
Two lacerations, small bowel	4	Lap belt
Torn mesentery and omentum	4	Lap belt
Abrasion right iliac crest	1	Lap belt
Abrasion (4x4 cm), left iliac crest	1	Lap belt
Fractured left foot	2	Lower driver seat frame

This occupant spent a total of 37 days in two hospitals, plus an extended period of outpatient care. At 7 months after the crash, he was still unable to return to work.

The severe (AIS 4) injuries sustained by this man can be attributed directly to the lap belt. The presence of abrasions on both the right and left iliac crests indicate that the belt was, at some point during the deceleration, placed in the area considered proper. The fracture of the right iliac crest indicates that the belt was positioned over that crest as severe loading of the webbing occurred. The small bowel is located in the mid-abdominal area, just above the iliac crest, and approximately centered between the second and fourth lumbar vertebrae. The injury-producing travel of the lap belt can be traced by the injuries.

The nature of the driver's seatback configuration, located directly forward of this man, did not allow containment of his upper torso and head travel. With his travel path being forward to the right, his head probably struck the sloping right side of the driver's seatback. This action allowed his upper torso and head to continue forward and downward, with the abdominal cavity being penetrated by the lap belt. Had the driver's seatback afforded containment of this passenger's upper body and head travel, the critical abdominal injuries probably would not have occurred, as the major deceleration would have been into the seatback instead of into the 2-inch-wide lap belt webbing.

Had this occupant not been wearing the lap belt, the dissipation of impact forces would have occurred over a much larger area. Given the driver's seatback configuration, he probably would have forcefully contacted that seatback, then twisted inboard into the center area between the front bucket seats. His loading of the driver's seatback possibly would have contributed enough additional forces through the driver's body, into the restraint system, for serious torso injuries to the driver, however.

Thus, the nature and extent of this passenger's injuries would have been much different if he had not been wearing the lap belt. The Delta V 38+ mph would certainly have resulted in injury of some type, but a comparison of this man's injuries to those of the persons seated unrestrained alongside him suggests they would have been much lower. Certainly this man would not have sustained the many serious to severe head, spine, and intra-abdominal injuries induced by the lap belt if his upper torso had been restrained in a lap/shoulder belt.

The forward folding of his seatback did not contribute to his injury. At the time that the seatback was bending forward under loading by the second bench passengers, this man had already traveled forward several inches, probably more than a foot, into the lap belt. Maximum loading of his seatback occurred simultaneously with maximum loading of his lap belt. In short, his lower body was out of position when the seatback folded.

Seating location: Bench 1, center
Sex: F
Age: 20
Height: 5 feet 6 inches
Weight: 240
Restraint used: None
Proper use? NA

This woman was not wearing the available static lap belt. Forward of her seating position, the engine cover had been displaced during the crash, with rearward distortion of the instrument panel area. The engine cover itself was not available for inspection.

Injuries	AIS	Probable Source
Fractured fibula, left	2	Engine and engine cover
Fractured tibia, left	2	Engine and engine cover
Deep laceration, left leg below knee	2	Engine and engine cover
2nd degree burns, lower left leg	1	Engine
Laceration, right knee	1	Engine cover
Hairline fracture, unspecified hip	2	Engine cover

She spent 5 days in an area hospital; several followup visits were required for treatment of complications. Three to 6 months of work were lost as a result of the accident.

If she had been wearing a lap belt, it could be reasonably expected that she would have experienced abdominal injuries similar to those of the man seated next to her on the left. There was no seatback forward of her position to provide any type of containment; thus, all deceleration would have been into the 2-inch-wide belt. Considering her obesity, there is little possibility that even a properly positioned and tensioned lap belt could have remained in proper position during the deceleration forces of this impact. The belt probably would have ridden up, over the iliac crest, into the abdominal cavity. With a properly positioned lap/shoulder belt, she would not have sustained the fractures, burn, and lacerations to her legs.

Seating location: Bench 1, extreme right
Sex: M
Age: 21
Height: 6 feet
Weight: 205
Restraint used: None
Proper use? NA

This man was not wearing the available static lap belt. The right front bucket seatback cushion directly forward of him was displaced. The extreme right side of the first bench seat ends several inches inboard of the vehicle interior sidewall, so that he was centered behind the inboard or left side of the right front bucket seat.

Injuries	AIS	Probable Source
Abrasion, forehead	1	Right front seatback
Abrasion, upper left leg	1	Engine cover
Superficial laceration, left elbow	1	Engine cover
Abrasion, right flank	1	Right front seatback
Contusion, right knee	1	Right front seatback

He was treated and released at a hospital; he said he was unable to work for 1 week.

This man's forward travel was mostly contained by the seatback cushion of the right front seat. Following the major deceleration provided by the seatback, he probably twisted inboard into the area between the front seats. The nature of his injuries enable the tracing of this travel path. The abrasions and contusion to his body's right side are from the cushion seatback, while the left side injuries are probably from the engine and damaged engine cover.

Seating location: Bench 2, extreme left
Sex: M
Age: 21
Height: 5 feet 1 inch
Weight: 130
Seated height: 30 inches
Restraint used: Lap belt (static)
Proper use? Probably

This man was wearing a static lap belt with a cinching type of latchplate attached to and adjustable on a 46-inch length of webbing, and a pushbutton release type of buckle attached to a 9-inch length of webbing. The tubular supports of this second bench were bent forward at the top, 3 inches on the left side and 3 3/4 inches on the right side. The extreme top of the second bench seatback cushion was displaced forward several inches, but accurate documentation was not possible, due to alteration during extrication efforts. Further examination of the position compartment revealed severe distortion of the first bench seatback directly forward of this occupant. The tubular framework located at the top of the first bench back cushion was bowed forward and down approximately 4 1/2 inches at its center point. A circular indentation was found in the top surface of the cushion material at 12 to 14 inches inboard of the extreme left side. Additionally, the tubular supports for the first bench were bent forward, 4 inches at the left side and 3 inches at the right side. There were no webbing scars found at this position.

Injuries	AIS	Probable Source
Unspecified laceration, forehead	1	Bench 1 back cushion
Contusion, area of both eyes	1	Bench 1 back cushion
Depressed frontal skull fracture	3	Bench 1 back cushion
LeFort III maxillary fracture	4	Bench 1 back cushion
Closed head injury	2	Bench 1 back cushion
Unspecified laceration, right foot	1	Bench 1 seat framework

This man spent 4 months in a hospital for treatment before being transferred to an extended care facility. Seven months after the crash he was still under extended care and on full disability.

The absence of abdominal contusions or abrasions indicates that his knees probably contacted the rear of the first bench at or before the major force loads of the impact. This type of contact would prevent the lap belt from traveling over the iliac crests into penetration of the abdomen.

The lap belt used by this occupant provided sufficient restraint of the lower body for a pivoting action, about the lap belt, to occur. This pivoting action of the upper body mass resulted in the occupant's face striking down into the uppermost tubular steel framework of the first bench seatback. Had this occupant not been wearing the lap belt, his deceleration probably would have been with a major portion of his upper body into the seatback in front of him, rather than his head into the seat framework and his lower body into the lap belt. Under these circumstances, his injuries probably would not have been so severe. A lap/shoulder belt also would have prevented this dangerous pivoting action and its resultant head injuries.

Seating location: Bench 2, center
Sex: M
Age: 18
Height: 5 feet 8 1/2 inches
Weight: 150
Seated height: 34 inches
Restraint used: None
Proper use? NA

This man was not wearing the static lap belt available at his seating position. In front of him was severe distortion to the first bench seatback and lower framework. The tubular steel seat top frame was bowed forward and down approximately 4 1/2 inches, and the lower seat framework supports were bent forward, 4 inches on the left and 3 1/2 inches on the right. The second bench seat was found with its left side support posts bent forward 3 inches and the right side posts bent 3 3/4 inches. This occupant said that he was displaced from his seat but he was unaware of his postcrash location.

Injuries	AIS	Probable Source
Left leg sprain	1	Bench 1 seatback
Left elbow sprain	1	Bench 1 seatback
Laceration (3 inch), just below left knee	1	Bench 1 lower framework
Lacerations, lower right leg	1	Bench 1 lower framework
Lacerations, lower left leg	1	Bench 1 lower framework
Pain in left shoulder	0	Bench 1 seatback

He was treated and released at a hospital. He said he lost 10 days of work due to his injuries.

This man's forward travel was contained by the seatback of the first bench. Without the lap belt restraint to restrict forward travel of his lower body, he was allowed to decelerate with dissipation of force spread over a major portion of his body. The energy management provided by containment is demonstrated by the minor injuries sustained by this passenger.

Seating location: Bench 2, extreme right
Sex: M
Age: 16
Height: 6 feet
Weight: 125
Seated height: 36 inches
Restraint used: None
Proper use? NA

This man was not wearing the static lap belt available at his seat position. The first bench back was bent forward approximately 3 inches at the right side tubular frame supports. The tubular supports of the second bench were bent forward 3 3/4 inches directly under this man's seating position. The upper framework of the first bench seatback was displaced forward in front of this man an undetermined distance. He said his postcrash position was in the floor area between the first bench and the second bench.

Injuries	AIS	Probable Source
Laceration to forehead(19 stitches), with caudal avulsion (wearing sunglasses)	2	Bench 1 seatback
Abrasion, left upper ankle	1	Bench 1 lower framework
Abrasion, right knee	1	Bench 1 seatback
Abrasion, left knee	1	Bench 1 seatback
Contusion, right elbow	1	Cargo floor area
Contusion, left elbow	1	Cargo floor area
Minor lacerations, right shoulder	1	Exit through side window
Minor lacerations, right hand	1	Exit through side window
Minor lacerations, left hand	1	Exit through side window

This man was treated and released at a hospital. He said he lost 7 to 9 days of work.

Clearly, containment also worked at this position. The moderate injury level (rather than minor, as with the unrestrained seat mate to his left) was the result of the extreme outside edge of the forward seatback being more rigid than at the center. This additional rigidity is due to the outboard vertical framework.

Seating location: Bench 3, extreme left
Sex: M
Age: 17
Height: 5 feet 7 inches
Weight: 180
Seated height: 34 inches
Restraint used: None
Proper use? NA

This man was not wearing the static lap belt available at his seat position. The Safety Board's examination of the area forward of this position revealed the uppermost framework of the second bench seatback was displaced forward several inches, with a further bow reaching an additional 3 1/2 inches at top center. The lower tubular supports for the second bench were bent forward, 3 inches on the left side and 3 3/4 inches at the right side. The framework beneath the third bench was bent forward, 4 inches on the left side and 6 1/2 inches at the right side. The right front base support anchor beneath this seat was found to be separated from the lower seat framework.

Injuries	AIS	Probable Source
Fracture, left distal radius	2	Bench 2 seatback
Mild concussion	2	Bench 2 seatback
Abrasion, lower right leg	1	Bench 2 lower frame
Abrasion, lower left leg	1	Bench 2 lower frame

He was treated and released at a hospital. He stated that almost 1 month of work was lost as a result of the accident injuries.

Containment worked again at this position, as the forces acting upon this man were allowed to dissipate over the major bulk of his body rather than be concentrated at narrow body areas.

Seating location: Bench 3, center
Sex: M
Age: 17
Height: 6 feet
Weight: 143
Seated Height: 37 inches
Restraint used: None
Proper use? NA

This man was not wearing the static lap belt available at his position. The top of the second bench seatback was displaced forward several inches in front of this man, with a 3 1/2-inch bow found in the top center tubular framework. The lower supports for the second bench were bent forward, 3 inches on the left side and 3 3/4 inches on the right side. The tubular supports of the third bench were bent forward, 4 inches on the left side and 6 1/2 inches on the right side. He said he was leaning over the seatback of the bench in front of him (second bench) following the crash.

Injuries	AIS	Probable Source
Contusion, nose	1	Bench 2 center occupant
Abrasion, right lower leg	1	Bench 2 lower frame
Unspecified right hip injury	0	Bench 2 seatback
Abrasion, right knee	1	Bench 2 seatback
Unspecified injury, medial lower left thigh	0	Bench 2 seatback
Unspecified injury, medial lower right thigh	0	Bench 2 seatback

He was treated and released at a hospital. He said he was able to return to work immediately.

Containment also worked for this occupant.

Seating location: Bench 3, extreme right
Sex: M
Age: 20
Height: 5 feet 10 inches
Weight: 175
Restraint used: None
Proper use? NA

This man was not wearing the static lap belt available at his position. The Safety Board's examination of the forward area for this position revealed the top portion of the second bench seatback was displaced forward several inches in the crash. The right side tubular framework supports for the second bench were bent forward 3 3/4 inches, and the right side back cushion framework was broken at its junction with the lower cushion frame. The right side tubular framework supports for the third bench, directly below this position, were bent forward 6 1/2 inches. The front base support on the right side of the third bench was separated from the body of the seat. This occupant recalled being thrown into the right side floor area.

Injuries	AIS	Probable Source
Contusion, right shoulder	2	Vehicle interior side
Contusion, right thigh	1	Vehicle interior side
Laceration, right shoulder	1	Vehicle interior side
Abrasions, back of neck	1	Exit through broken side glass

He was treated and released at a hospital and reported no loss of work as a result of his injuries.

Although this man was displaced from his seating position, the major impact forces probably were dissipated through contacts of his upper body and leg with the second bench seatback as he was leaving his seat. This prevented serious injury.

Seating location: Bench 4, extreme left
Sex: M
Age: 17
Height: 5 feet 5 inches
Weight: 150
Restraint used: None
Proper use? NA

This man was not wearing the static lap belt available at his seating position. The top framework of the third bench seatback, located forward of his position, was displaced forward several inches. The lower tubular support posts for the third bench were bent forward 4 inches, and the top center framework was bowed forward 1 1/2 inches. The tubular support posts for the fourth bench, directly below this occupant, were undeformed. With the seatback cushion of the third bench bent forward, the bolt heads and metal plates used for attaching the belt webbing for the third bench were exposed on the rearmost lower cushion framework.

Injuries	AIS	Probable Source
Closed head injury	2	Bench 3 seatback
Fracture, right scapula	2	Bench 3 seatback
Laceration, right lower leg (victim stated 6 inches)	1	Bench 3 lower frame
Contusion, left lower leg	1	Bench 3 lower frame
Contusion, right ankle	1	Bench 3 lower frame
Contusion, central chest	1	Bench 3 seatback
Contusion, right eye	1	Bench 3 seatback

He was treated and released at a hospital. He said he lost about 1 week of work.

This unrestrained man's forward movement was contained by the seatback of the third bench; like the unrestrained man at the third bench, extreme left, he sustained only minor to moderate injuries. The containment effect allowed him to ride down the severe Delta V with dissipation over a large body area.

Seating location: Bench 4, right center
Sex: M
Age: 17
Height: 5 feet 10 inches
Weight: 135
Restraint used: Lap belt (static)
Proper use? Probably

This man was wearing a static lap belt with a cinching type of latchplate, adjustable on a 53-inch length of floor-anchored webbing, and a pushbutton release type of buckle. The buckle webbing, 34 inches long, was also floor-anchored, and both portions of webbing for the system passed through the junction of the upper and lower seat cushions. The belt anchoring method caused lateral separation of 40 inches between the two floor anchor points. The seatback of the third bench, directly forward of this position, was deformed forward several inches at its uppermost edge. One of the seat cushion stiffeners was also

deformed forward. Further examination of this position found the spare tire of the vehicle unattached, lying directly below this seating position (14), on the cargo floor.

Injuries	AIS	Probable Source
Fractured left radius	2	Bench 3 seatback
Fractured left fibula	2	Bench 3 lower frame and unsecured spare tire
Fractured left tibia	2	Bench 3 lower frame and unsecured spare tire
Lacerations to arms	1	Postcrash vehicle exit
Abrasions to arms	1	Postcrash vehicle exit
Numerous abrasions to face	1	Bench 3 seatback, postcrash vehicle exit
Numerous lacerations to face	1	Bench 3 seatback, postcrash vehicle exit
Unspecified urinary tract injury	7	Lap belt

This man said that following the crash a friend helped him get out of the vehicle through a broken side window. He rolled and tumbled down a 45° embankment for about 15 feet. This man was in a hospital for 1 week, followed by an extended period of followup. He said that 4 months of recovery time was required before he could return to work.

The facial injuries sustained by this lap belted occupant were less severe than those of the lap belted men on the first and second benches, probably due to the less rigid contact surface furnished by the center area of the third bench upper seatback, and/or to the fact that he attempted to brace himself.

The injury mechanism of his lower leg injuries was the unsecured spare tire, which moved forward during the crash and struck his legs. Had the spare tire been secured properly, it is unlikely that the extreme lower fractures could have occurred.

Had this occupant not been restrained, it could be assumed that his injury level would have been similar to that sustained by other center seated occupants--i.e., minor to moderate. (However, this assumption does not consider the unsecured spare tire.)

Seating location: Bench 4, extreme right
Sex: M
Age: 20
Height: 5 feet 6 inches
Weight: 128
Restraint used: Lap belt (static)
Proper use? Probably not

This man was wearing a static lap belt with a cinching type of latchplate, adjustable on a 45-inch length of webbing, and a pushbutton release type of buckle attached to a 44-inch length of webbing. Both webbing sections entered the seat position area by passing between the junction of the seat cushions. He said that his lap belt tension was snug but could not state the position about his body.

The seatback of the third bench was displaced forward several inches directly forward of this occupant's position. The extreme right side of the third bench was directly forward of the approximate longitudinal center of his position. On the cargo floor, directly forward of him, a raised tire well is located adjacent to the interior sidewall. The fourth bench tubular support posts at the extreme right were bent forward 5 inches. There was no deformation noted at the back cushion of the fourth bench.

Injuries	AIS	Probable Source
Torn sigmoid colon	5	Lap belt
Torn mesentery	4	Lap belt
Torn serosa of jejunum	4	Lap belt
Fracture, 5th lumbar vertebra	3	Lap belt
Cauda equina (nerve root) injury	3	Lap belt
Contusion, right ankle	1	Cargo floor tire well
Fracture, left 1st rib	1	Right side, bench 3 seatback

Only major injuries were noted in detail on this man's hospital records. No detailed information was supplied as to contusions and abrasions about his body. It was noted, however, on the emergency room reports, that he was tender in the left upper quadrant of the abdomen.

He spent 2 months in a hospital. Following discharge, he required outpatient care about once a month. Seven months after the accident, he had not returned to work and stated that he was on disability.

The critical abdominal injuries sustained by this man can be attributed directly to the lap belt he was wearing. His kinematics can be easily traced by the nature and location of his injuries. The forward travel of his upper body resulted in a fracture of the T-1 left side rib as that body area struck the extreme right side of the third bench seatback. (That seatback is offset inboard from the right approximately 12 inches to allow a passageway.) With the reactive travel forward and slightly to the right, this man's upper body was not contained, and a jackknife action over the lap belt resulted. His entire deceleration was into the 2-inch-wide lap belt. The nature of his internal abdominal injuries and the fracture at the L5 vertebra indicate abdominal penetration by the restraint webbing.

The belt webbing at this seating position was anchored to the cargo floor, 19 inches below and 4 inches behind the undeformed junction of the seat cushion. Anchored in this manner, the webbing would have provided a downward force as it was loaded by his body during the crash. If the lap belt had been positioned below this man's iliac crests, the nature of the system's anchors and routing over the metal framework of the lower cushion probably would have prevented it from riding up. Thus, the lap belt probably was above the top of the long iliac crests prior to the deceleration forces.

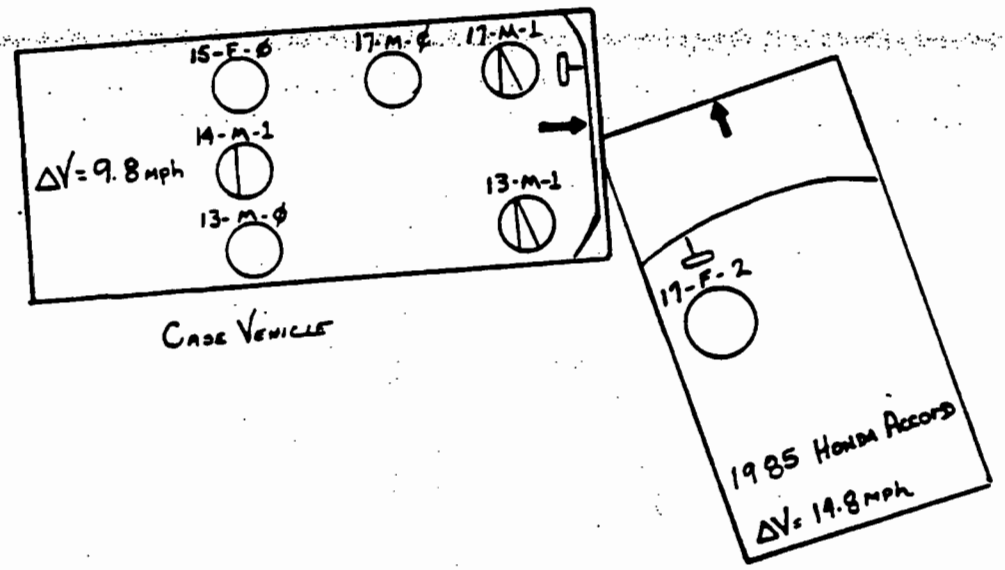
Another factor which probably affected this man's injury severity was the lateral separation between the latchplate and buckle webbing anchors, along with the placement of those anchors in relation to the longitudinal centerline of the seating position. It seems that, under severe force loads, the belt webbing would generate a lateral compression force. As forward loading of the belt webbing increases, the lateral compressive forces into an occupant's abdomen would also increase. With the left side webbing routed out and around the occupant's left side, the maximum compressive forces would occur on that side. A check of his hospital records verify that speculation: his most severe abdominal injuries were located in the lower left quadrant.

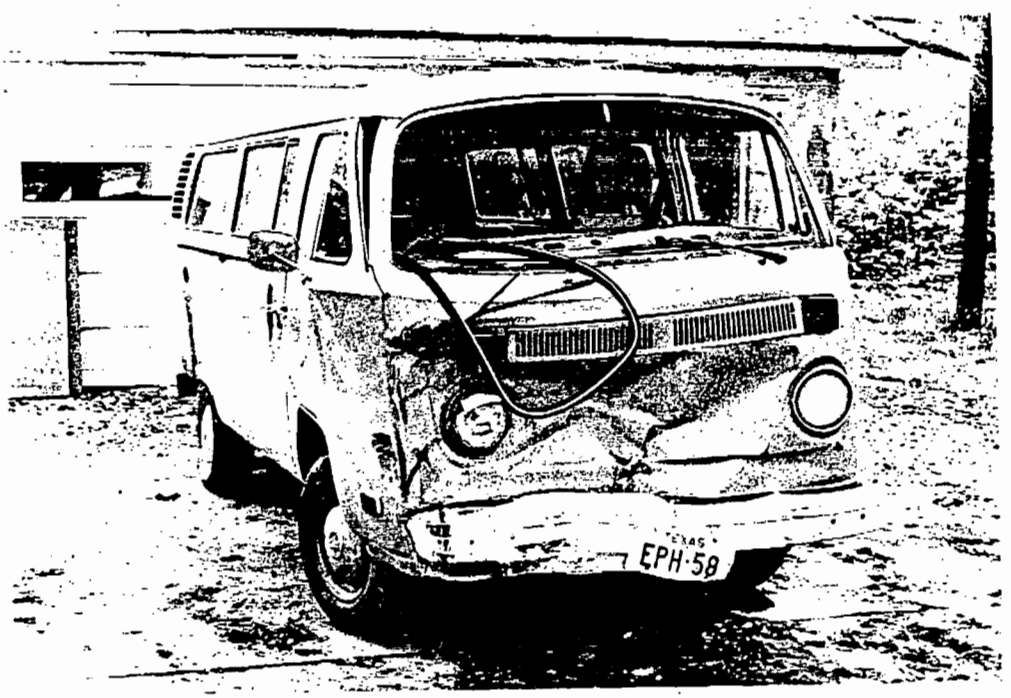
An analysis of probable results had this man not been wearing the lap belt is difficult. There would have been little containment provided by the third bench seatback forward of him, due to the 12-inch inboard offset. This passenger's body mass would have been thrown forward and partially contained on the left side. The twisting effect of this deceleration probably would have resulted in various fractures of his extremities, specifically to his lower legs. Fractures of his right side extremities also could have occurred, due to forceful contact with the cargo floor and tire well.

If this man had been restrained in a lap/shoulder belt, he probably would have sustained only minor to moderate injuries.

CASE 5 (FTW-85-H-OR31)

Case vehicle: 1976 Volkswagen Van
Case vehicle weight: 4,000 pounds
Case vehicle Delta V: 9.8 mph





Circumstances

A 1976 VW Van struck, front center, a 1985 Honda Accord on the left front corner. The van was driven by a 17-year-old boy wearing the available static lap/shoulder belt. There were 5 other occupants of the van: a 13-year-old boy in the right front, restrained by a static lap/shoulder belt; a 15-year-old girl in the left rear, unrestrained; a 14-year-old boy in the center rear, with a static lap belt around him; a 13-year-old boy in the right rear, unrestrained; and a passenger riding on the cargo area floor of the van. Damage was substantial to both vehicles and both required towaway removal from the accident scene.

The collision resulted in moderate injuries to the unrestrained driver of the Honda. The restrained driver of the van, although misusing his restraint by wearing the shoulder belt portion routed under his left arm, sustained only minor injuries, as did the lap/shoulder belted right front passenger. The boy riding in the center rear seat with a lap belt received minor injuries also, apparently due to disconnection of the buckle at impact. The remaining occupants, all unrestrained, were not injured.

Restraint and Injury

Seating location: Driver
Sex: M
Age: 17
Height: 6 feet 2 inches
Weight: 175
Seated height: 35 inches
Restraint used: Lap/shoulder belt
Proper use? No

This boy was wearing a lap/shoulder belt with two separate lengths of webbing, joined by a cinching adjustment device, that formed an adjustable length, continuous loop belt, with free sliding latchplate. The latchplate coupled with a rigid stalk-mounted buckle attached to the seat pedestal framework. At the time of the impact, he was wearing the shoulder strap improperly routed under his left arm. The steering assembly was displaced forward approximately 2 inches.

Injuries	AIS	Probable Source
Fractured metacarpal (left)	2	Steering wheel rim
Soreness in upper right shoulder without contusion	0	Impact forces

He attributed his left hand injury to his attempt at bracing against the impact forces. He sought medical attention for this injury, was treated and released.

Given the configuration of the van's interior in front of the driver, it is probable that some degree of injury would have been sustained even if the shoulder strap had been routed properly. While the underarm strap routing contributed to an excessive slack in the webbing, there was also simply not enough clear space forward of the driver to avoid a contact with the steering assembly. Although this boy suffered no reported abdominal or chest injuries, the steering assembly displacement must have come about through some contact from his body. It is unlikely that the wheel displacement came about through his attempt to brace himself with his left arm. A 175-pound boy almost certainly could not

hold himself back from the steering assembly with one arm while decelerating through a vehicle speed change of approximately 10 mph, especially when very little upper torso restraint was provided by the improperly routed shoulder strap.

Had this boy been unrestrained, a moderate level of injury could have been expected in this crash.

Seating location: Right front
Sex: M
Age: 13
Height: 5 feet 8 inches
Weight: 135
Restraint used: Lap/shoulder belt
Proper use? Yes

This boy was wearing a lap/shoulder restraint made up of two lengths of webbing, joined by a cinching type of adjustment device, that formed an adjustable length, continuous loop, system with free-sliding latchplate. The latchplate coupled with a rigid stalk- mounted buckle that extended up and forward from its seat pedestal attachment point. This boy's description of system adjustment indicated proper routing and belt tension. The front interior forward of this occupant was collapsed rearward approximately 10 inches, substantially reducing the clear space available. The vehicle's windshield was also displaced from its framework, leaving the unfinished framework edges open to possible occupant contact.

Injuries	AIS	Probable Source
Contusion, upper right shoulder and chest	1	Shoulder strap
Contusion, lower right leg just above ankle	1	Collapsed frontal interior

This boy did not require treatment for his injuries. The lower leg contusion he suffered resulted from interior compression directly in front of him. In a vehicle with collapsible front components other than sheetmetal, this leg injury almost certainly would not have occurred.

Had he not been restrained, even with the relatively low Delta V of this crash, it is very likely that serious injuries would have resulted. Since the windshield was displaced from its framework, it would have been quite possible for him to have been ejected, or partially ejected, through this space (see the right front occupant in Case 4). Even without ejection, severe contacts with the blunt windshield framework would have occurred. This boy's lack of serious, life-threatening injuries can be attributed directly to his (proper) use of and the good performance of the lap/shoulder belt at his position.

Seating location: Rear center
Sex: M
Age: 14
Height: 5 feet 11 inches
Weight: 170
Restraint used: Lap belt (static)
Proper use? Probably not

Before the accident, this boy was wearing a static lap belt. His description of precrash belt adjustment was that the webbing was loosely positioned low on his hips, resting on top of his thighs. He said that immediately after the crash, he found himself on the cargo floor of the van. He could not recall with certainty, but thought that the belt was still routed around him. There were several items lying unsecured in the cargo area, including a 5-gallon plastic bucket.

Injuries	AIS	Probable Source
Small laceration in right eybrow line	1	Interior loose cargo
Abrasion to right knee	1	Cargo floor area

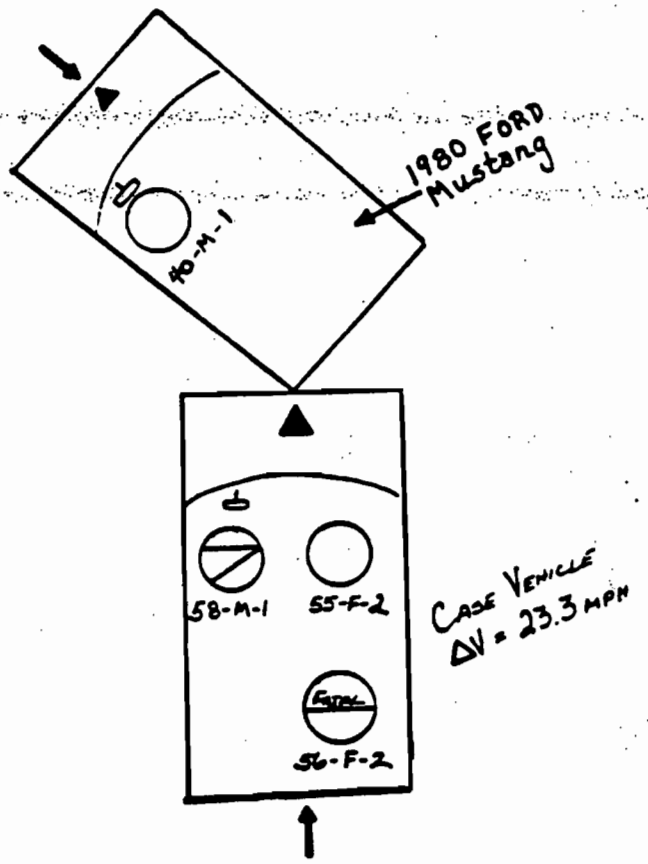
He visited a local emergency clinic for treatment of his minor injuries.

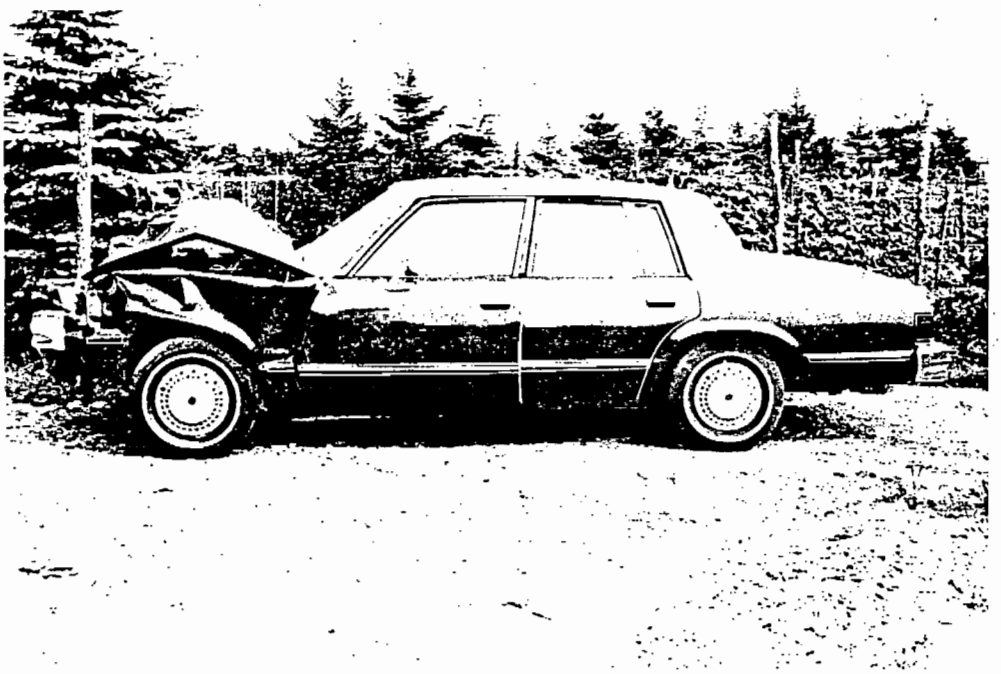
Postcrash webbing measurements showed that the total webbing length of this lap belt could not have allowed the boy to end up on the floor with the latchplate still coupled into the buckle. It is clear that the buckle/latchplate connection must have failed, but it is not readily apparent why it failed. Safety Board investigators were able to secure the connection, postcrash, with no visible defects. Of course, it was not possible to apply force loads similar to those which occurred at the impact, but it is clear that a load of more than 450 pounds did not cause the separation. The absence of load marks on the webbing indicates that the connection failed before or at the very beginning of the imposition of crash loads. It is possible that the connection was not securely fastened by the occupant in the first place.

There were three other young people riding in the rear of the van. A 15-year-old girl was riding unrestrained at the left rear seat position and was not injured. A 13-year-old boy was riding unrestrained at the right rear position and was uninjured. A 17-year-old boy sitting unrestrained on the floor was not injured.

CASE 6 (NYC-84-H-OR05)

Case vehicle: 1983 Chevrolet Malibu, 4-door
Case vehicle weight: 3,690 pounds
Case vehicle Delta V: 23.3 mph





Circumstances

A 1983 Chevrolet Malibu was struck in the front center by the left rear corner of an out-of-control 1980 Ford Mustang. The Chevrolet was occupied by 3 adults, 2 of whom were wearing seat belts: the driver, a 58-year-old man, was wearing a lap/shoulder belt; the right rear passenger, a 56-year-old woman, was wearing a lapbelt. The right front passenger, a 55-year-old woman, was unrestrained.

As a result of the crash, the unrestrained Mustang driver and the front seat occupants of the Chevrolet received minor injuries. The lap belted woman in the right rear of the Chevrolet died soon after arriving at the hospital.

Restraint and Injury

Seating location: Driver
Sex: M
Age: 58
Height: 6 feet
Weight: 270
Restraint used: Lap/shoulder belt (ELR)
Proper use? Yes

The Chevrolet driver was wearing a continuous loop, lap-shoulder belt with a locking latchplate and windowshade type of tension relief device. The ELR was vehicle sensitive.

Injuries	AIS	Probable Source
Chest pain along shoulder belt line	0	Shoulder belt
Mild neck strain	1	Flexion
Contusion, front lower left leg	1	Contact with hardware
Contusion, front lower right leg	1	Under dashboard

This man was examined and released at a hospital.

Seating location: Right front
Sex: F
Age: 55
Height: 5 feet 6 inches
Weight: 160
Restraint used: None

Injuries	AIS	Injury Source
Laceration (2 inch), left temple	2	Rear view mirror
Neck strain	1	Rearward flexion when head struck windshield moulding and visor
Contusion, forehead, both eyes, cheekbone below eye	1	Contact with upper windshield moulding and visor
Soreness above left breast	0	Unknown
Multiple abrasions, discoloration left arm	1	Steering wheel, gear shift, instrument panel instrument panel
Multiple abrasions and discoloration both legs	1	Dashboard, glove compartment
Sprained ankle	1	Floorboard

This woman was treated and released at a hospital.

Since the Chevrolet experienced sudden deceleration and clockwise rotation at impact, the occupants (due to inertia) moved forward and left. This unrestrained woman crashed into the car's interior and received the minor to moderate injuries noted above. If she had worn (properly) the available lap/shoulder belt, she probably would have escaped much of this injury. However, this woman stated that, except for occasional use on a long trip if she is driving, she does not wear seat belts because they are "uncomfortable."

Seating location: Right rear
Sex: F
Age: 56
Height: 5 feet 8 inches
Weight: 155
Restraint used: Lap belt (ALR)
Proper use? Yes

This woman was wearing a lap belt with an ALR. At impact, she also was thrown forward. The lap belt pressed into her abdomen, restraining her pelvis while her upper torso jackknifed over the belt. Her head and legs hit the back of the right front seat, but much of the deceleration force was concentrated at her abdomen by the belt, apparently causing serious intra-abdominal injuries. Since no autopsy was performed, however, the precise nature of her internal injuries was not determined. Circumstantial evidence, however, indicates that she probably suffered internal abdominal injuries that caused severe hemorrhaging and led to her death. The emergency personnel reported that this woman complained of stomach pain, nausea, tingling sensation in the extremities, and difficulty in breathing. At the scene, and en route to the hospital, the emergency technicians encountered difficulty in getting a blood pressure reading—it was weak and

hard to find. They also noted that her abdomen was very swollen. The emergency room physician said he believed this swelling was due to internal hemorrhaging, consistent with the tingling sensation in the extremities and the difficulty in getting blood pressure readings.

The woman died within minutes of arriving at the hospital.

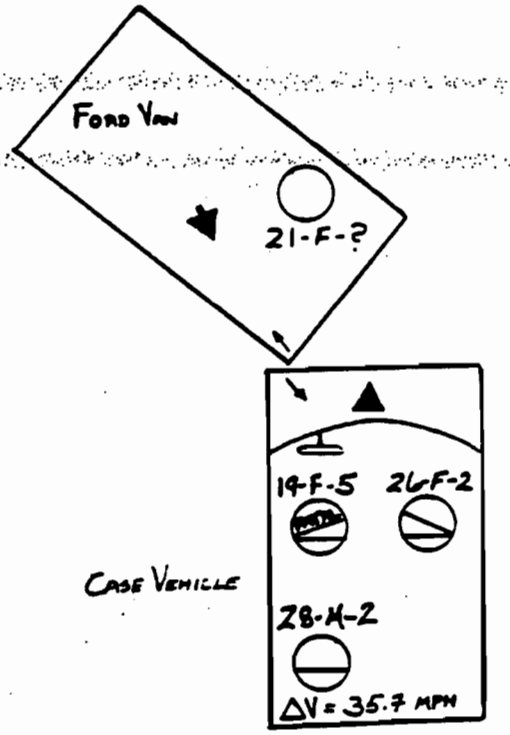
Injuries	AIS	Injury Source
Fracture (probable), nose	1	Front seatback
Contusion, left eye	1	Front seatback
Distended abdomen, with 3-inch bruise along lap belt line, about 2 inches below umbilicus, extending from iliac crests	2	Lap belt
Pelvis, rib pain	7	Unknown

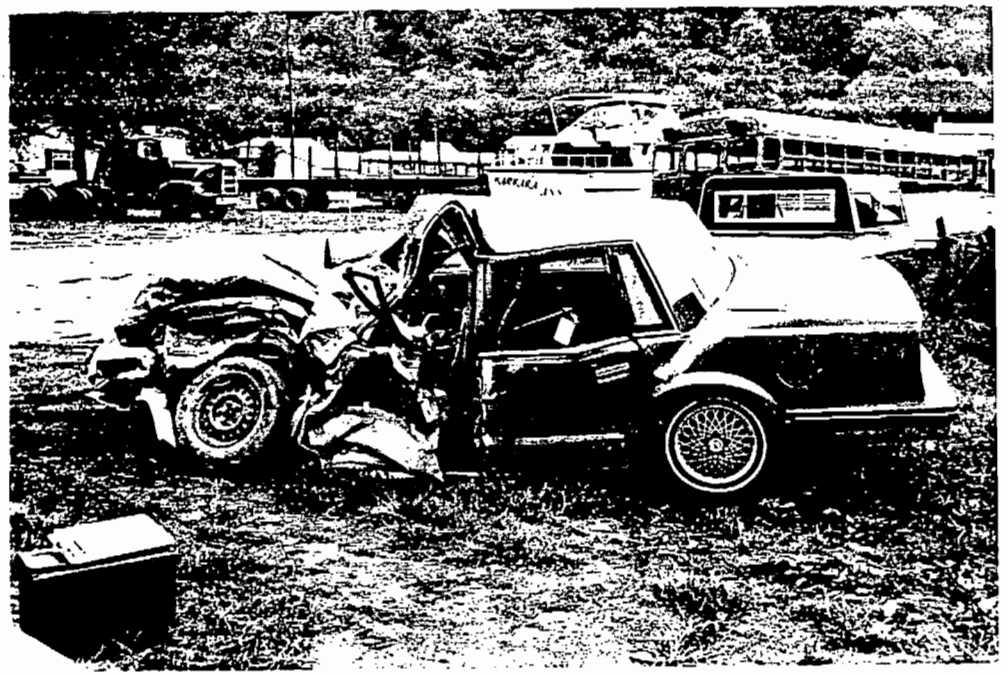
The woman's fatal injuries cannot be attributed to improper belt use or improper belt fit, the Safety Board believes, because the location of the belt contusions on her abdomen indicate that the belt was on the iliac crests at the moment of loading--thus, considered to be within the proper fit zone. Given the level of injuries sustained by the unrestrained front seat passenger, it is reasonable to believe that this rear seated woman would have fared much better if she had not been wearing her lap belt, or if she had been restrained by a lap/shoulder belt.

This case is of special interest because it offers an opportunity to compare the crash outcomes for three persons experiencing similar crash forces but each representing a different restraint situation: the lap/shoulder belt, the lap belt, and unrestrained. Furthermore, the crash was of only moderate severity, and the unrestrained woman and the lap belted woman were of closely similar size. The unrestrained woman was also seated in a more hostile position than the lap belted woman. It is thus important to note the substantial discrepancy between the level of injuries sustained by the right front, unrestrained woman and the lap belted woman sitting in the rear seat behind her. Not surprisingly, the lap/shoulder belted driver fared relatively well; surprisingly, the unrestrained front passenger also fared much better than the lap belted rear passenger.

CASE 7 (CHI-85-H-OR02)

Case vehicle: 1984 Chevrolet Celebrity, 4-door
Case vehicle weight: 3,172 pounds
Case vehicle Delta V: 35.7 mph





Circumstances

A 1984 Chevrolet Celebrity was struck on the left front corner by the right front corner of a 1984 Ford van. The Chevrolet was driven by a 19-year-old woman; a 26-year-old woman was in the right front, and a 28-year-old man was in the left rear. Both front seat occupants were restrained by 3-point lap/shoulder belts, while the rear seat passenger was wearing a lap belt. Both vehicles received substantial front structural damage.

The crash caused critical head injuries to the Chevrolet driver as the front structure collapsed rearward into the driver's space. The driver was pronounced dead 7 1/2 hours after the crash without regaining consciousness. The right front passenger and left rear passenger both sustained multiple moderate to serious injuries.

Restraint and Injury

Seating location: Driver
Sex: F
Age: 19
Height: 5 feet 5 inches
Weight: 122
Seated Height: 27 inches
Restraint used: Lap/shoulder belt (ELR)
Proper use? Yes

This woman was wearing a 3-point, continuous loop, lap/shoulder belt with a vehicle motion sensitive ELR, a cinching type of latchplate, and a pushbutton release type of buckle mounted to a flexible stalk. The restraint system also had a windowshade type of tension relief device, operational only with the position door closed.

The A pillar, instrument panel, and steering assembly were collapsed rearward several inches forward of this seating position; in fact, extrication tools were required to remove this occupant from the crushed interior. The driver's seat was in full foward position.

This collision was probably not survivable for the Celebrity driver, due to the compression of her seating position. The impact forces resulted in several inches of rearward displacement to the steering assembly and B pillar. Had the principal impact area not been located to the left side of the major structural components, the fatal injuries should not have occurred, since the injury-producing contact points would not have been reachable by a fully-restrained driver.

Injuries	AIS	Probable Source
Loss of consciousness (1-24 hours) with neurologic defect	5	Transmitted force, head contact with A pillar
Laceration (2 inches), left parietal scalp	2	A pillar
Laceration (1 1/2 inches), left supraorbital	1	A pillar
Depressed skull fracture, left frontal area	3	A pillar
Traumatic subarachnoid hemorrhage	3	Transmitted forces
Cerebral contusion	3	Transmitted forces
Depressed maxillary fracture	2	A pillar
Abrasions, multiple, left eyelid	1	A pillar
Fracture, right sternum at junction with ribs	2	Steering assembly
Abrasions, left pectoral chest	1	Door side-glass
Contusion, right lower abdomen	1	Steering wheel and/or lap belt
Contusion, junction of abdomen and right thigh	1	Steering wheel and/or lap belt
Closed fracture, right femur	3	Transmitted force from instrument panel
Closed fracture, left femur	3	Transmitted force from instrument panel
Contusion, right thigh	2	Steering assembly
Contusion, posterior surface, left knee	1	Instrument panel and below, collapsed lower A pillar, interior sidewall
Abrasion, left mid-tibial region	1	Instrument panel and below, collapsed lower A pillar, interior sidewall
Contusion, left mid-tibial region	1	Instrument panel and below, collapsed lower A pillar, interior sidewall

This driver reportedly did not regain consciousness following the accident. She was transported to two different hospitals before being pronounced dead approximately 2 1/2 hours later. The official cause of death was multiple injuries with diagnosis of acute craniocerebral injury.

Seating location: Right front
Sex: F
Age: 28
Height: 5 feet 5 inches
Weight: 130
Seated height: 27 1/2 inches
Restraint used: Lap/shoulder belt
Proper use? Yes

This woman was wearing a 3-point, continuous loop, lap/shoulder belt similar to the driver's. Her seat was in full forward position. Though the instrument panel was pushed rearward at this location, the amount of compartment compression was not nearly as great as that which occurred forward of the driver.

This occupant probably rode down the crash forces as well as could be expected. Due to the angular force line, she came from behind the shoulder strap and struck either the steering assembly or the instrument panel with her head. This movement from behind the shoulder strap has been found in other cases involving angular force lines and probably should not be considered a failure with a Delta V of almost 36 mph acting at approximately 40° to 50° from the vehicle's precrash longitudinal travel path.

Injuries	AIS	Probable Source
Laceration, left eyelid	1	Instrument panel or steering wheel
Fractured nose	1	Instrument panel or steering wheel
Contusion, right shoulder to left abdomen	2	Shoulder belt webbing
Contusions, hips and abdomen	1	Lap belt webbing
Abrasion, left hip	1	Buckle and stalk
Fractured pelvis	2	Lap belt
Laceration (4 inch) with avulsed tissue, left lateral thigh	2	Instrument panel parts
Contusion, left lateral ankle	1	Collapsed underpanel
Contusion, right shin	1	Collapsed underpanel
Laceration, left heel	1	Collapsed underpanel
Scratches, right hand	1	Windshield

This passenger was in a hospital for 6 1/2 days and was off work for 1 month.

Seating location: Left rear
Sex: M
Age: 28
Height: 5 feet 7 inches
Weight: 145
Seated height: 30 inches
Restraint used: Lap belt (ALR)
Proper use? Yes

This man was restrained by a lap belt with an ALR, a sewn-in latchplate attached to the retractor webbing, and a sewn-in pushbutton release type of buckle attached to a short length of webbing. The buckle webbing entered the seating area by passing between the seat cushion junction; the latchplate webbing passed over the outboard edge of the lower seat cushion approximately 2 to 3 inches forward of the seat cushion junction.

There was a slight compartment compression at this seating position due to the rearward displacement of the left side B pillar, along with rearward displacement of the lower outboard driver's seat.

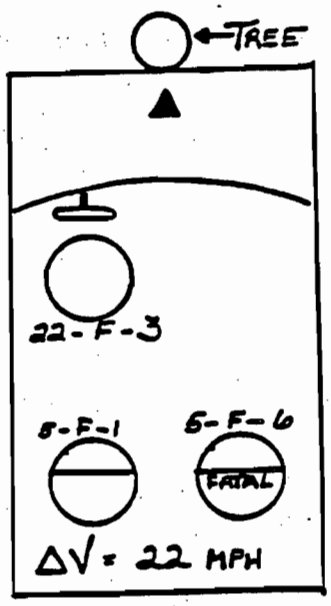
Due to the angular force line, this passenger was subjected to a 33-mph longitudinal Delta V out of the total Delta V 35.7 mph. The lateral speed change component allowed his deceleration to be somewhat contained by the left interior sidewall and B pillar instead of entirely into the 2-inch-wide lap belt webbing. Had he been subjected to an actual 12 o'clock force line and undergone the entire Delta V 35.7 mph longitudinally, the lap belt would have been his major deceleration point. This could very easily have resulted in major internal injuries, since little containment would have been provided by the fully forward driver's seat. It would be extremely difficult to speculate a lesser degree of injury had he not been lap belted, since his travel path to the most severe injuries would have been very similar.

Injuries	AIS	Probable Source
Laceration (3 inch), above left eye	2	B pillar, side-glass
Lacerations (two 1 1/2 inch each), below left eye	2	B pillar, side-glass
Lacerations (two), above right eye	1	B pillar, side-glass
Contusion, large, left side face	2	B pillar, side-glass
Fracture, left mandible	2	B pillar, side-glass
Fracture, left zygoma	2	B pillar, side-glass
Contusion, left parietal scalp	1	B pillar, side-glass
Laceration, left parietal scalp	1	B pillar, side-glass
Abrasions, left shoulder	1	B pillar, side-glass
Lacerations (superficial), left shoulder	1	Side-glass
Contusion, abdominal	2	Lap belt
Laceration, small, left finger	1	Side-glass

He was in a hospital for 8 1/2 days. He was off work for 2 months.

CASE 8 (CHI-85-H-OR19)

Case vehicle: 1977 Chevette, 2-door hatchback
Case vehicle weight: 2,261 pounds
Case vehicle Delta V: 22 mph



Circumstances

A 1977 Chevrolet Chevette sedan, driven by an unrestrained 22-year-old woman with two lap belted 5-year-old girls in the rear seat, ran off the road and hit a tree center front. Following this moderate crash, the three ocupants were transported to a hospital by ambulance. The unrestrained driver received serious injuries, and the lap belted child in the left rear had minor injuries. The lap belted child in the right rear was fatally injured.

Restraint and Injury

Seating location: Driver
Sex: F
Age: 22
Height: 5 feet 6 inches
Weight: 160
Restraint used: None

Injuries	AIS	Injury Source
Fractured right femur	3	Instrument panel
Contusion, right lung	2	Steering assembly
Abrasion, sternum	1	Steering assembly
Fractured pubic bone	2	Steering assembly
Laceration, left knee	1	Instrument panel
Laceration, right knee	1	Instrument panel
Laceration, scalp	2	Windshield
Contusion, right side face	1	Unknown
Abrasion, left elbow	1	Unknown
Abrasion, left shoulder	1	Unknown

Seating location: Left rear
Sex: F
Age: 5
Height: 43 inches
Weight: 41
Seated height: 19 inches
Restraint used: Lap belt (ALR)
Proper use? Perhaps too high

Injuries	AIS	Injury Source
Abrasion, right side forehead	1	Driver's seatback
Abrasion, right upper lip	1	Driver's seatback
Abrasion, left thigh	1	Lap belt
Abrasion across lower abdomen at umbilicus	1	Lap belt

This child was admitted to a hospital only for observation. Although a witness stated that the lap belt worn by this child was tightly adjusted and worn low on the hips, which indicates proper fit and position, the abrasion across the abdomen at the umbilicus suggests that the belt may have been too high.

(See discussion below regarding this child's kinematics.)

Seating location: Right rear
Sex: F
Age: 5
Height: 43 inches
Weight: 41
Seated height: 19 inches
Restraint used: Lap belt (ALR)
Proper use? Probably

Injuries	AIS	Injury Source
Disarticulation of skull from spinal cord (2 cm separation of head from spinal column with torn ligaments; no vertebrae fractures)	6	Impact force
Deep purple bruise at right iliac crest and lower abdomen below umbilicus	1	Lap belt
Bruise of head and face	1	Victim's legs, or seat cushion
Bruise over right eye	1	Victim's legs or seat cushion
Small bruise, left chest	1	Legs, or CPR

This child was found unconscious in the right rear seat by a passing motorist who was first on the scene. He said that the child was wearing a lap belt which he described as fitting tight and positioned low on the hips. He unbuckled the child and removed her from the car. He placed her on the side of the road and administered CPR. When she was removed to the hospital, she was put on a life support system, but never regained consciousness. She was pronounced dead about 18 hours after the crash. No autopsy was performed. The cause of death was listed as severe spinal cord injury with head injury.

Based on the statement of the first person on the scene, and the bruises to the iliac crest and lower abdomen, it is believed that the lap belt was worn within the proper fit zone, if at the upper limit.

Since no autopsy was performed on the fatally injured child, the disarticulation of the skull cannot be certainly attributed to hyperextension (overstretching) or hyperflexion (overbending); it could have been either. Initially, the Safety Board investigation surmised that, during impact, both lap belted children in the rear seat jackknifed forward over their lap belts and struck their heads on the seatbacks in front of them. According to this analysis, the great dissimilarity in the two girls' injuries resulted from the difference in the track adjustment of the seats in front of them--since the right front seatback was

5 inches further forward than the left front seatback, the right rear seat passenger's neck stretched before her head struck the rear seat, causing the fatal injury. However, though this scenario may be possible, on further analysis, the Board concludes the available evidence does not convincingly support it.

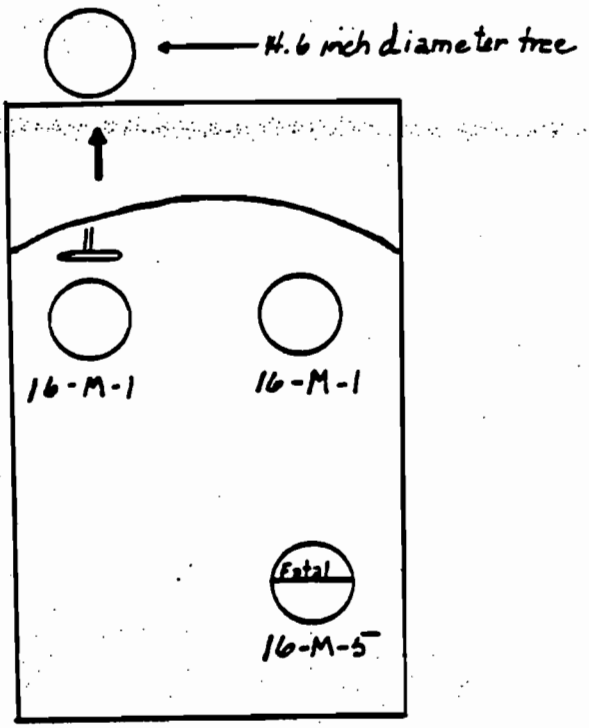
Rather, it is probable, based on the children's 19-inch seated height, their facial injuries, and the location of the clear contact point on the backs of the front seats, that neither child's head struck the seatback in front of her. Since both children were only 43 inches tall, it is likely that, when belted into the car's rear seat, their lower legs did not flex down over the front edge of their seat cushion, but projected straight out. When the car crashed into the tree, the children's bodies moved straight forward and, if anything, their shoes contacted the backs of the front seats while their upper torsos jackknifed over their lap belts and their heads came face down onto their legs or the seat cushion they were seated on, or both. The degree of injury resulting from this type of kinematic is not predictable and likely depends on head attitude combined with leg orientation. (Similar kinematics were involved in bringing about the fatal spinal cord injuries in the similar size boy wearing a lap belt in Case 10.) However, we can be certain that if the children had been lap/shoulder belted they would not have jackknifed forward, and both would have survived. Their survival would not have been left to chance.

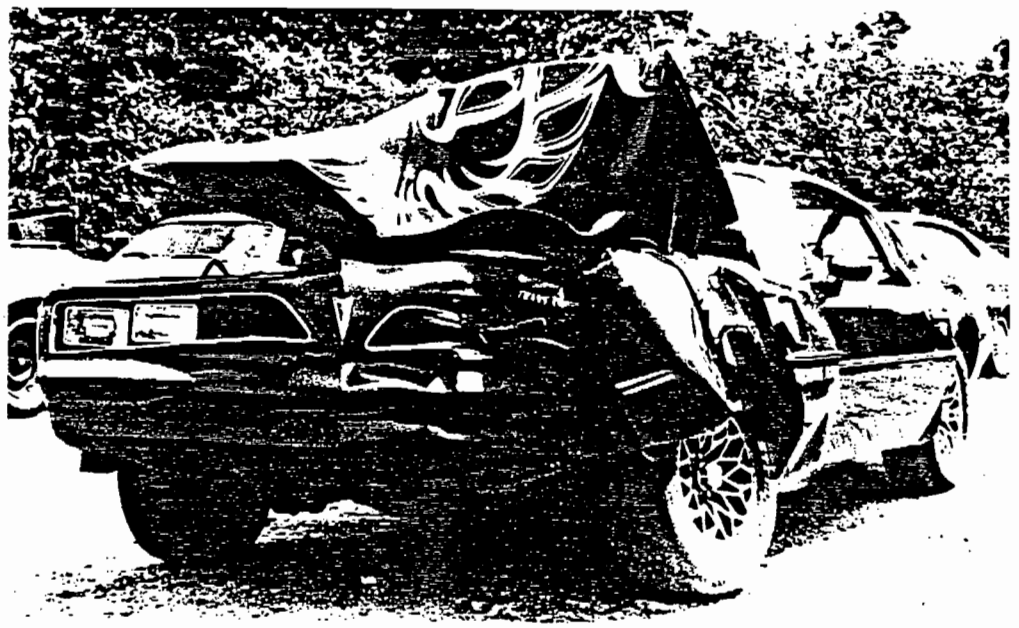
This case illustrates an important type of lap belt related injury: head and cervical spine injury resulting from jackknifing forward over the lap belt. Young children may be more vulnerable to this type of injury than are adults.

Finally, although it was clearly evident from the case facts that the fatally injured child was not ejected from the car, both the ambulance and hospital records stated that this child was thrown from the vehicle into a ditch. While it is uncertain what effect this erroneous information had on the evaluation and treatment of the child's injuries, it is vital that emergency room physicians be provided with accurate information regarding the injury-producing mechanics, particularly with unconscious crash victims, to assist them in evaluating the injuries so that treatment will be prompt and appropriate.

CASE 9 (ATL-84-H-OR29)

Case vehicle: 1977 Pontiac Trans Am
Case vehicle weight: 3,940 pounds
Case vehicle Delta V: 26.4 mph





Circumstances

A 1977 Pontiac Trans Am struck a 14.6-inch-diameter tree head-on but left of center. The impact caused front structural collapse of 25 inches on the car. The car was occupied by an unrestrained 16-year-old male driver, an unrestrained 16-year-old boy in the right front, and a 16-year-old boy in the right rear. This boy was restrained by the latchplate webbing of his seating position coupled into the buckle assembly of the seat to his left.

The crash resulted in minor injuries to the front seated occupants. The right rear passenger sustained serious, and ultimately fatal, intra-abdominal and spinal injuries. All occupants were transported to a hospital, where the driver and right front passenger were treated and released. The right rear passenger was admitted to the hospital and received treatment for 25 days before he died.

Restraint and Injury

Seating location: Driver
Sex: M
Age: 16
Height: 5 feet 10 inches
Weight: 160
Restraint used: None
Proper use? NA

Injuries	AIS	Probable Source
Mild abrasion to left side of chest	1	Steering assembly
Hematoma, left lower mandible	1	Steering assembly

Seating location: Right front
Sex: M
Age: 16
Height: 6 feet 1 inch
Weight: 175
Restraint used: None
Proper use? NA

Injuries	AIS	Probable Source
Perineal tear	1	Impact forces

Seating location: Right rear
Sex: M
Age: 16
Height: 5 feet 11 inches
Weight: 150
Restraint used: Lap belt (ALR)
Proper use? No

This boy was wearing a lap belt combination which used the latchplate webbing system furnished for the right rear seat and the buckle system provided for the left rear seating position. It had an ALR for the latchplate webbing and a pushbutton release type of buckle mounted to a short length of webbing passing through the seat cushion junction. His use of the left side buckle assembly was necessary due to the inaccessibility of the right position assembly, but it introduced several inches of lateral separation between the restraint anchor points.

Following is a list of the injuries sustained by this occupant:

Injuries	AIS	Probable Source
Fracture/dislocation of thoracic spine at T-11, T-12	2	Lap belt
Total transection of spinal cord at T-11, T-12	5	Lap belt
Ruptured spleen	4	Lap belt
Ruptured left kidney	5	Lap belt
Ruptured duodenum	5	Lap belt
Ruptured head of pancreas	5	Lap belt
45 mm fracture of right kidney	5	Lap belt
1 to 2 cm contusion on liver	3	Lap belt
Abdominal contusions, upper	1	Lap belt
Left ankle abrasions	1	Front seat assembly
Right knee abrasions	1	Front seat assembly

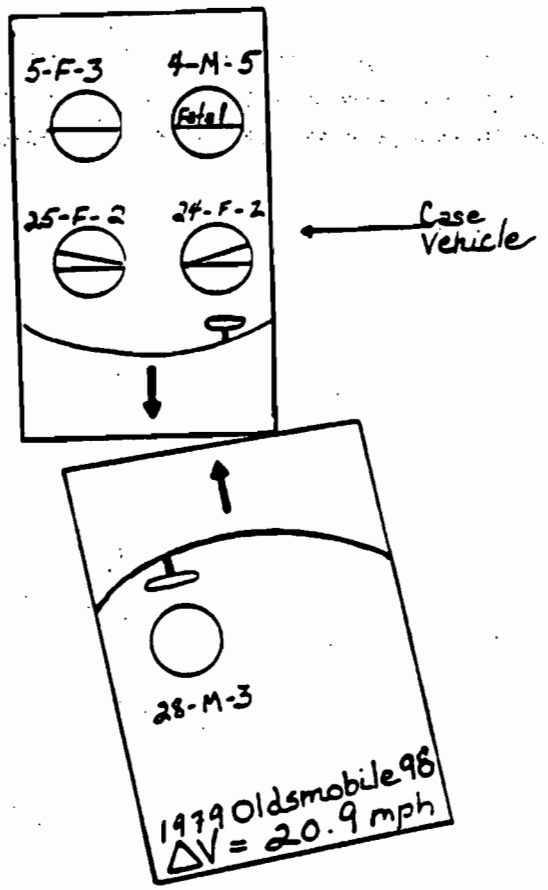
It seems apparent from reviewing the medical records that the major restraining force of the lap belt was concentrated in the upper abdominal area of the victim. The hospital records indicate contusions to the upper abdomen without mention of injuries in the lower area of proper belt routing. In addition to the upper abdominal contusions, all major organ damage was concentrated in the upper area of the abdominal cavity.

The Safety Board concludes that the improper latchplate/buckle coupling was not solely responsible for this boy's injuries. The additional 6 to 8 inches of lateral separation resulting from connecting the right position latchplate into the left position buckle assembly should not, by itself, cause a properly routed lap belt to ride up several inches. The most probable explanation of the injuries is that a combination of three factors contributed: the improper coupling; a lap belt routing which placed the webbing well above the iliac crest; submarining of the occupant which forced the restraint webbing toward the upper area of the abdominal cavity.

In any case, given the nature and severity of the injuries sustained by the front occupants, it seems clear that this boy could have survived with minor or no injury if he had not been wearing a lap belt or had been wearing a properly fitted lap/shoulder belt.

CASE 10 (NYC-85-H-OR09)

Case vehicle: 1982 Subaru station wagon
Case vehicle weight: 2,715 pounds
Case vehicle Delta V: 32.3 mph



Circumstances

A 1982 Subaru station wagon was struck head-on by a 1979 Oldsmobile 98. At impact, the Subaru was stopped and pushed backward; the Delta V was 32.3 mph. The four Subaru occupants were restrained by seat belts. The two adults in the front seat (24-year-old woman driving and 25-year-old woman in right front) were wearing lap/shoulder belts. The two children in the rear seat (a 4-year-old boy in the left rear and a 5-year-old girl in the right rear) were both wearing lap belts.

The rescue squad and ambulances arrived soon after the collision and transported the occupants of both cars to a hospital. The Subaru driver and front seat passenger received moderate injuries, the lap belted 5-year-old in the right rear seat was seriously injured, and the lap belted 4-year-old in the left rear was fatally injured. The unrestrained 28-year-old man driving the Oldsmobile, the vehicle's sole occupant, was seriously injured.

Restraint and Injury

Seating location: Driver
Sex: F
Age: 24
Height: 5 feet 6 inches
Weight: 135
Restraint used: Lap/shoulder belt (ALR)
Proper use? Yes

This woman was wearing a continuous loop, lap/shoulder belt that had a free-sliding latchplate and a vehicle-sensitive ALR.

Injuries	AIS	Probable Source
Lacerated lip	1	Steering wheel
Laceration, right knee	2	Instrument panel
Fractured, right tibial plateau	2	Instrument panel
Fracture and dislocation of right foot	2	Foot control
Laceration, left elbow	1	Driver's door
Abrasion of lower abdomen	1	Steering wheel and/or lap belt

This woman was 12 to 13 weeks pregnant, but she was unaware of it. Her condition was discovered during the postcrash hospital examination. No sign of life was found in the fetus and it was aborted. She was released from the hospital 9 days after the accident.

Seating location: Right front
Sex: F
Age: 25
Height: 5 feet 7 inches
Weight: 130
Restraint used: Lap/shoulder belt
Proper use? Yes

This woman was wearing a lap/shoulder belt similar to the driver's. She suffered the following injuries:

Injuries	AIS	Probable Source
Laceration of left eyelid	1	Unknown
Contusion lower abdomen	1	Lap belt
Fractured, left tibia	2	Dash panel
Contusion, right leg	1	Unknown
Contusion, left thigh	1	Unknown
Contusion, left hip	1	Lap belt

This woman also spent 9 days in the hospital.

Seating location: Right rear
Sex: F
Age: 5
Height: 40 inches
Weight: 35
Restraint used: Lap belt (ALR)
Proper use? Yes

This child sustained the following serious injuries, all induced by the lap belt:

Injuries	AIS	Probable Source
Abrasion, lower abdomen	1	Lap belt
Hematoma, small bowel	3	Lap belt
Retroperitoneal hematoma of lower left abdominal area	3	Lap belt
Mesenteric tear, sigmoid colon	3	Lap belt
Hematoma, sigmoid colon	3	Lap belt
Bilateral fracture of L4	2	Lap belt
Hematoma of the conus medularis (cone-shaped lower end of spinal cord)	7	Lap belt

Her severe abdominal and lumbar spine injuries occurred despite the fact that she seems to have been wearing the lap belt in the proper location. A laparotomy was performed on this girl 2 days after the crash. She was transferred to two other hospitals before being released about 4 months later. She now wears leg braces and must use a "walker" for mobility.

Seating location: Left rear
Sex: M
Age: 4
Height: 40 inches
Weight: 38
Restraint used: Lap belt (ALR)
Proper use? Yes

This child was found unconscious after the crash, and remained unconscious until he was pronounced dead 2 days later. The cause of death was listed as cerebral edema with anoxic changes (changes from lack of oxygen in the brain) and severe contusion of the spinal cord from subluxation of the cervical spine.

Injuries	AIS	Probable Source
Abrasion, right side of forehead	1	Unknown
Severe contusion of cervical spinal cord	3	Unknown
Subluxation of cervical spine (C2-C3)	3	Unknown
Fracture, thoracic spine (T-2)	2	Unknown
Abrasion of thorax at sternum cleft	1	Unknown
Abrasion, right shoulder	1	Unknown
Abrasion, left shoulder	1	Unknown
Brain edema	3	Unknown
Hematoma on back at T-2	1	Unknown
Abrasion, left iliac crest	1	Lap belt
Abrasion, right iliac crest	1	Lap belt
Unconscious more than 24 hours	5	Unknown

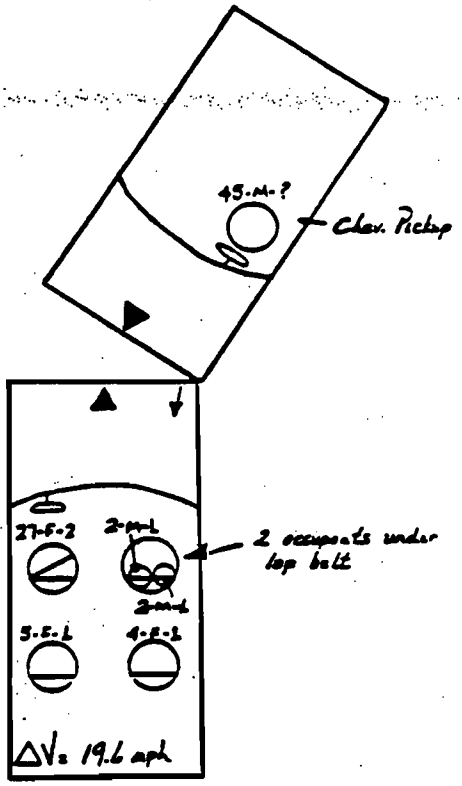
The medical examiner's report on this child's death states that he was apparently wearing a seat belt but that it might have been loose and that the boy was "bounced within the car." These statements are examples of the poor understanding by some medical personnel of motor vehicle crash injury causation. They illustrate how uninformed but official statements have contributed to continued dismissal of lap belt injuries as being caused solely by inappropriate use of the belt.

There is no support for the medical examiner's statements in this case. The facts indicate that the boy was wearing the lap belt in the proper way, that it was snug, and that it fit him in the way lap belts are supposed to fit. The belt is fitted with an automatic locking retractor which is tension loaded and automatically takes up any belt slack and locks the belt in place. Thus, it is highly unlikely that it could have been worn "loosely." There were abrasions on the boy's left and right iliac crests, which indicate that the pelvic area was restrained at impact and that the lap belt was worn within the zone considered to be proper. It appears that the belt performed as designed: it retained the pelvic area and permitted the unrestrained upper torso to jackknife forward over the lap belt. Based on his injuries, the Safety Board surmises that when the boy's upper body jackknifed over the belt, his shoulders struck his legs and his head went down between his knees, causing the spinal cord, spine, and shoulder injuries. (There were similar kinematics involved in causing the fatal cervical spine injuries in the 5-year-old girl wearing a lap belt in Case 8.) Finally, the boy was found lap belted and leaning over on the child in the right rear seat; no interior evidence of contact suggests that the boy was "bounced within the car."

The Safety Board concludes that both these children would have sustained substantially less severe injuries and both would have survived had their upper bodies been restrained along with their pelvises, by the proper use of rear seat lap/shoulder belts.

CASE 11 (ATL-85-H-OR14)

Case vehicle: 1977 Plymouth Arrow, 2-door
Case vehicle weight: 2,395 pounds
Case vehicle Delta V: 19.6 mph



Circumstances

A 1977 Plymouth Arrow struck a 1985 Chevrolet S-10 pickup, right front into left front. The longitudinal Delta V for the car was 14 to 17 mph; the total Delta V was 19.6 mph. The car was occupied by a lap/shoulder belt restrained 27-year-old female driver, 4- and 5-year-old girls in the rear who were lap belt restrained, and two 2-year-old boys seated under a lap belt at the right front.

This moderate crash resulted in moderate injuries to the restrained driver of the Plymouth and minor injuries to all four lap belted children. All were transported to a hospital where they were treated and released. The Plymouth driver required further care from a private physician for treatment of a knee injury and was unable to work for 2 weeks. No visible injury was reported by the unrestrained driver of the Chevrolet pickup.

Restraint and Injury

Seating location: Driver
Sex: F
Age: 27
Height: 5 feet 11 inches
Weight: 110
Restraint used: Lap/shoulder belt (ELR)
Proper use? Yes

The Plymouth driver was wearing a 3-point, continuous loop, lap/shoulder belt with an ELR sensitive to webbing travel, a free-sliding latchplate, and a pushbutton release type of buckle attached to a flexible stalk. A force load mark from the free-sliding latchplate was found 36 inches above the lower outboard webbing anchor. There were no force loading scars on the D-ring area webbing.

An inspection of the driver's interior compartment revealed no compression of the occupiable space. A white area of fabric abrasion was found on the left side of the steering column, just rearward of the lower surface of the instrument panel. The driver related that, at the time of the crash, she was wearing white jeans.

The restraint system adjustment at this position was described as snug with the webbing positioned across the abdomen. The shoulder strap webbing placement was shown by injury photographs to be above the right side of the mid-chest area and the driver indicated the strap to be without excessive slack.

Injuries	AIS	Probable Source
Major contusion, lower abdomen	2	Lap belt
Cervical strain	1	Transmitted forces
Contusion, left clavicle area	1	Shoulder strap
Contusion, mid right chest	1	Shoulder strap
Contusion, left knee,	1	Steering column
Contusion, right knee, medial	1	Steering column
Abrasion, right lower arm	1	Steering wheel rim
Abrasion, medial left ankle	1	Foot pedal controls

Seating location: Right front, inboard
Sex: M
Age: 2
Height: 36 1/2 inches
Weight: 35
Seated height: 20 inches
Restraint used: Lap belt
Proper use? No

This toddler boy was riding on the inboard portion of the right front bucket seat alongside another 2-year-old boy. They were both restrained by the lap belt webbing of a continuous loop, lap/shoulder restraint with the shoulder strap routed behind their backs. The belt system was similar to the driver's.

The driver said that the lap belt was positioned low across the children's hips and snug. There was a 3-inch-long force loading scar at the latchplate adjustment position. The webbing was found folded over itself at the point where it passed through the free-sliding latchplate. There was no loading mark from the D-ring.

Inspection of the right front passenger compartment revealed a depressed area of the vinyl padded instrument panel, just above the upper left corner of the glove compartment door. Light colored hair was embedded in the damaged vinyl surface.

Injuries	AIS	Probable Source
Laceration (1/2 inch), right forehead	1	Instrument panel
Abrasion, right forehead	1	Instrument panel
Abrasion, right eyelid	1	Instrument panel
Contusion, lower right abdomen	1	Lap belt
Contusion, lower right abdomen	1	Lap belt

This boy was treated and released from a hospital.

Seating location: Right front, outboard
Sex: M
Age: 2
Height: 37 1/2 inches
Weight: 25
Seated height: 20 inches
Restraint used: Lap belt
Proper use? No

This child was riding on the outboard portion of the right front bucket seat, restrained with another 2-year-old boy under the lap belt webbing of a 3-point restraint system with the shoulder strap webbing routed behind their backs. (For description of restraint system, adjustment, and position compartment examination, see information on right front inboard passenger.)

Injuries	AIS	Probable Source
Laceration (5 stitches), right parietal scalp	1	Instrument panel
Abrasion, right temporal to right zygomatic	1	Instrument panel

The two small boys were improperly restrained in the right front bucket seat. Both were seated under the lap belt with the shoulder strap routed behind their backs. There was an excessive amount of webbing between the lower outboard anchor and the latchplate; either the lap belt was positioned around them with this excess slack or the excess was crash induced. The boys must have traveled forward and inboard several inches to make the contact with the instrument panel at the point documented by the investigation. There was probably little restraint provided by the lap belt at this position. A large portion of the crash energy acting on these occupants was probably dissipated by the interbelt contact between their bodies and the head strikes into the deeply padded instrument panel. A comparison between the lap belt induced abdominal bruising of these boys and those of the driver clearly show a large difference in restraining effect.

The absence of lap belt related abdominal bruising on the outboard seated child indicates that his body probably loaded the inboard seated child into the belt's webbing. The fact that the inboard occupant received abdominal bruising to both the right and left side reinforce this indication.

Seating location: Left rear
Sex: F
Age: 5
Height: 44 inches
Weight: 40
Seated height: 22 inches
Restraint used: Lap belt (ELR)
Proper use? Yes

This girl was sitting on the rear bench seat, restrained by a lap belt with an emergency locking retractor, a latchplate integrated into the retractor, and a pushbutton release type of buckle. There was no apparent interior compartment deformation nor webbing scars due to force loading of the lap belt.

Injuries	AIS	Probable Source
Contusion, mid to lower left abdomen	1	Lap belt and retractor
Contusion, upper left thigh	1	Lap belt and retractor
Contusion, lower right abdomen	1	Lap belt
Extended period of soreness in abdomen	0	Lap belt

This occupant's lap belt was probably positioned low, across the top of her hips with a snug fit afforded by the retractor tensioning. There were no apparent contact points between the occupant and vehicle interior but it is highly probable, given the resultant force lines due to rotation, that the left side of the girl's head made contact with the vehicle interior sidewall. Her upper body probably hit her lower extremities, due to the jackknifing motion over the lap belt. This jackknife motion is well illustrated by the retractor induced contusions on her left upper thigh and lower left abdomen; these occurred as her body folded over the large retractor assembly. The angular forward motion of her upper body allowed the upper body contact with the lower extremities to occur over the upper surface of her left leg, preventing the head and neck injuries seen in similar crashes due to the head's travel downward between the lower extremities.

Seating location: Right rear
Sex: F
Age: 4
Height: 45 inches
Weight: 35
Seated height: 22 inches
Restraint used: Lap belt (ELR)
Proper use? Yes

This child was restrained in a manner similar to her seatmate in the left rear. There was no interior deformation at or forward of this seating position.

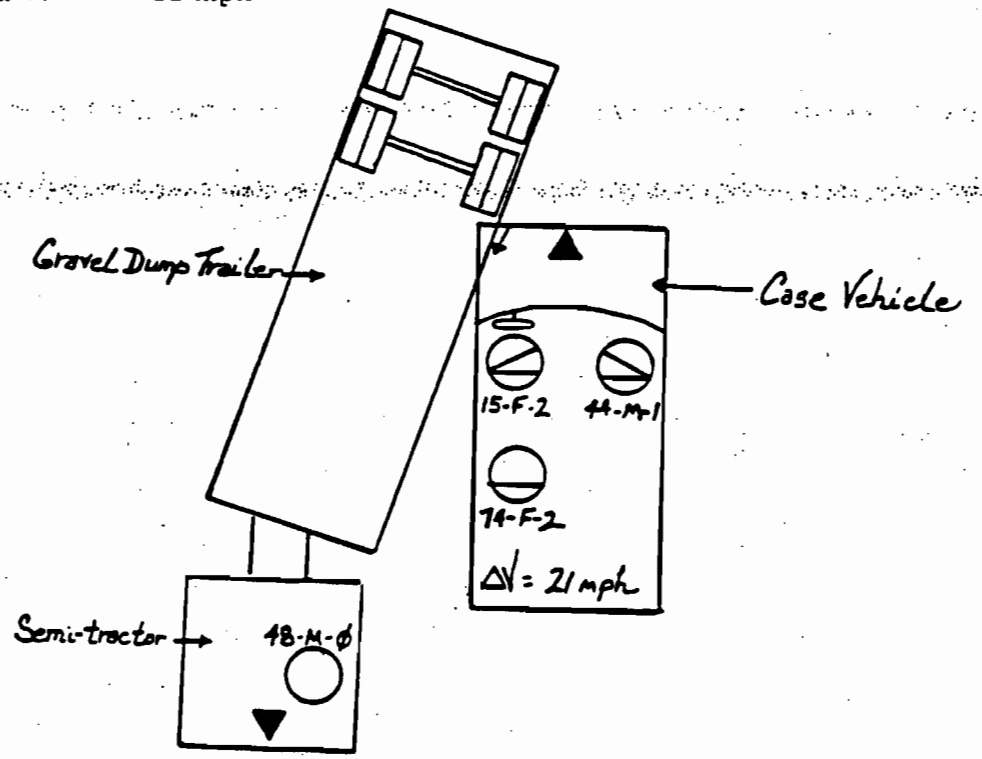
Injuries	AIS	Probable Source
Large contused area, left side mid-abdominal area	1	Lap belt
Contusion, front right hip	1	Lap belt and retractor
Contusion, upper right thigh, front	1	Lap belt and retractor
Extended period of soreness in abdomen	1	Lap belt

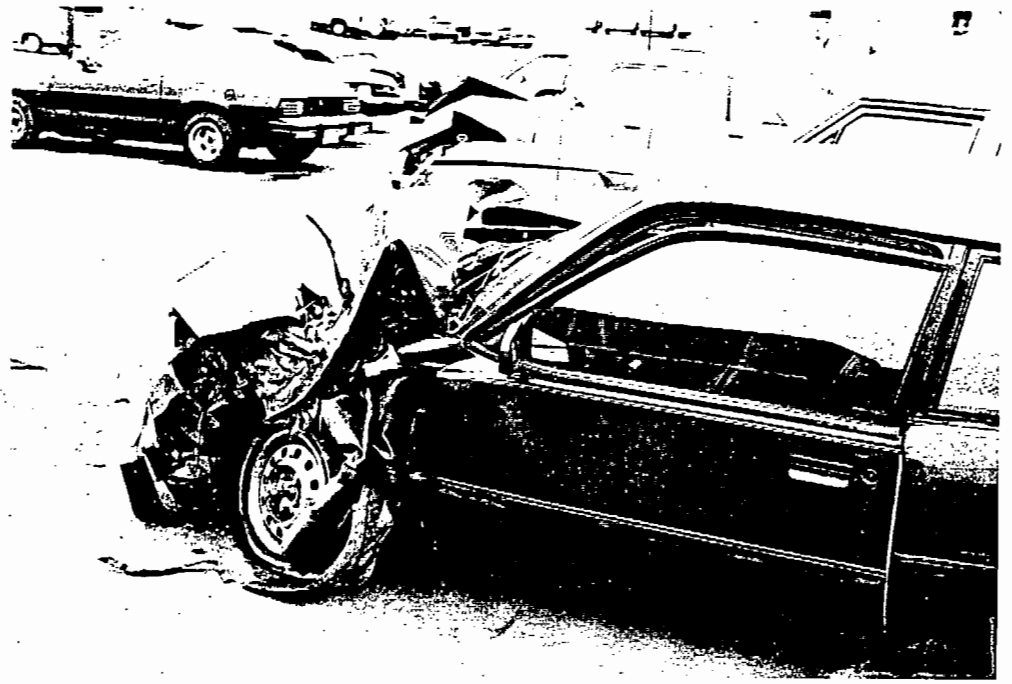
The right rear occupant's belt position was probably low across her hips prior to the crash. The abdominal contusion was lower on the right side, well below the iliac crest. The left side contusions appear to begin in the iliac crest area but extend upward into the side abdominal area. This riding up of the belt probably occurred due to the lateral acceleration following the initial impact. The left side of the lap belt would have been loaded as the upper body rotated forward and toward the left, thus allowing the belt to rise over the long iliac crest into an area of less resistance.

The jackknifing motion over the lap belt is also well illustrated by this occupant's contusion pattern. Again, the matching contusions due to folding over the retractor assembly are present, this time on the victim's right side. The resultant occupant travel, due to force line and vehicle rotation, was forward and to the left. This motion allowed her lower extremities to cushion the upper body contact and prevent the neck hyperflexion that occurred to other children in this study when their heads went far down between their legs.

CASE 12 (FTW-85-H-OR17)

Case vehicle: 1984 Chevrolet Cavalier, 2-door
Case vehicle weight: 2,920 pounds
Case vehicle Delta V: 21 mph





Circumstances

A 1984 Chevrolet Cavalier struck, left front corner first, the left leading dual tire assembly of a 42-foot dump trailer being pulled by a 1979 Ford semi-truck. The Chevrolet's left frontal structure was substantially damaged, with rearward displacement depths reaching 20 inches. The trailer unit received only minor damage and was not disabled.

This accident resulted in moderate injuries to the Chevrolet driver, a 15-year-old girl wearing a lap/shoulder belt; minor injuries to the right front passenger, a 54-year-old man wearing a lap/shoulder belt; and moderate to serious injuries to the left rear passenger, a 74-year-old woman wearing a lap belt. Both the driver and the left rear passenger required emergency aid and transportation to a hospital. The driver of the truck combination unit was not injured.

Restraint and Injury

Seating location: Driver
Age: 15
Height: 5 feet 1 inch
Weight: 125
Restraint used: Lap/shoulder belt (ELR)
Proper use? No

This girl was wearing the available 3-point, continuous loop, lap/shoulder belt with a vehicle motion sensitive ELR, a cinching type of latchplate, and a pushbutton release type of buckle attached to a flexible stalk. A windowshade type of tension relief device was also incorporated into the system. There was a webbing scar, from force loading of the cinching latchplate, 35 inches above the lower outboard anchor. Also found was an 8-inch-long area of vinyl transfer onto the shoulder strap webbing from the upper outboard seatback. A matching area of vinyl abrasion was noted on the seatback cushion. There were no webbing scars attributed to the B pillar-mounted D-ring.

The extreme left outboard instrument panel was displaced rearward by approximately 2 inches. The steering wheel rim was displaced forward about 2 1/2 inches at 9, 10, and 11 o'clock. The lowermost edge of the instrument panel was mildly deformed, and fabric scuffs were found at the left and right of the instrument panel. A plastic air duct, located under the instrument panel just to the left of the steering column, was shattered and displaced forward. This air duct was located directly forward of the left side fabric scuff. The seatback was deformed forward approximately 10 to 12 inches at the top.

Injuries	AIS	Probable Source
Deep abrasion with two areas of avulsions, left knee	2	Lower instrument panel
Right ankle sprain	1	Foot controls
Right ankle contusion	1	Foot controls
Contusion, abdominal muscle wall, lower left quadrant	1	Lap belt
Contusion, lower sternum	1	Steering assembly/shoulder restraint
Contusion, lower right chest	1	Steering wheel/shoulder restraint
Contusion, below left clavicle	1	Shoulder strap
Dislocated front teeth	1	Steering assembly
Abrasion, right knee	1	Lower instrument panel
Contusion, posterior upper left arm	1	Seatback cushion
Contusion, posterior upper right arm	1	Seatback cushion

The girl was treated and released at a hospital but required the use of crutches for 10 days.

A review of this girl's injuries, the apparent contact points within the vehicle, and the restraint webbing scars seem to indicate that the shoulder strap provided little or no restriction to upper body movement. A D-ring load mark should have been present in this type of impact if the upper body's forward movement loaded the webbing at impact. The shoulder strap was probably excessively slack; possibly this slackness was present because she set the "windowshade" tension relief incorrectly. This occupant should not have made the severe, rim-deforming, impact with the steering assembly with a properly adjusted restraint system. The vinyl transfer from the seatback onto the shoulder strap probably occurred as the seatback traveled forward, due to loading from the left rear passenger and due to distortion of the vehicle's floorpan. This loading probably took place just as the driver was striking the steering assembly.

This driver said that the lap belt was worn across her abdomen and that it was adjusted somewhere between loose and snug. This type of adjustment would also introduce slack into the shoulder strap as the lower belt system traveled through the cinching latchplate under load.

Seating location: Right front
Sex: M
Age: 44
Height: 6 feet 2 inches
Weight: 225
Restraint used: Lap/shoulder belt
Proper use? Yes

This man was wearing a lap/shoulder belt similar to the driver's. There was a webbing scar from force loading of the latchplate 33 inches above the lower outboard anchor. A second abrasion of the webbing fabric, 75 to 78 inches above the lower outboard anchor, was attributed to webbing travel through the B pillar-mounted D-ring. The seat was adjusted on its track at 5 1/2 inches from the forwardmost position and

1 1/2 inches from its extreme rear. There was no deformation of the seat assembly. Inspection of the forward compartment area at this position revealed a distorted area of the glove compartment: the compartment door was bent forward at the center of its lower edge, and the latching mechanism was broken.

Injuries	AIS	Probable Source
Contusion, chest wall	1	Shoulder belt
Contusion, left knee	1	Instrument panel
Abrasion, left wrist	1	Instrument panel
Contusion, right knee	1	Instrument panel
Contusion, lower right abdomen	1	Lap belt
Cervical strain	1	Transmitted forces

This man refused emergency treatment at the accident scene and transport by ambulance. He later sought treatment at a hospital, where he was released after being checked.

He apparently moved forward sufficiently within his lap/shoulder belt for knee contact with the instrument panel. He said the lap belt was across his abdomen but did not say whether the system was snug. Force loading marks on the webbing indicate that restraint was provided to both his upper and lower body. Considering the impact severity, the occupant's large body size, and the interior compartment dimensions of the case vehicle, it seems that the restraint system performed very well and was probably adjusted well.

Seating location: Left rear
Sex: F
Age: 74
Height: 5 feet 6 inches
Weight: 184
Restraint used: Lap belt (ALR)
Proper use? Yes

This woman was wearing a lap belt with an automatic locking retractor, sewn-in latchplate, and a pushbutton release type of buckle attached to a short length of webbing material. The uppermost surface of the driver's seatback, directly in front of this woman, was permanently deformed forward by several inches, and the lower surface of the seatback was pushed inward.

Injuries	AIS	Probable Source
Closed head injury, concussion	2	Transmitted forces
Deep (3 inch) laceration, right forehead	2	Contact with lower extremity
Major contusion/abrasion, left hip	2	Left interior sidewall
Major contusion, right side of face	2	Contact with lower extremity
Laceration, left forearm	1	Surface of driver seatback
Laceration, right forearm	1	Surface of driver seatback
Contusion, right lower chest	1	Contact with lower extremity
Foot laceration	1	Unknown
Lower left abdominal contusion	1	Lap belt
Contusion, right medial knee and below	1	Head contact
Contusion, right mid-abdomen	1	Lap belt

This woman was hospitalized for 1 day. There was no mention on the emergency treatment forms nor the hospital records indicating the use of a seat belt.

Although this woman described her lap belt as being positioned "across her abdomen," photographs of the belt induced contusion show that the belt was positioned below the iliac crest. The belt tension, as stated by the occupant, was somewhere between loose and snug.

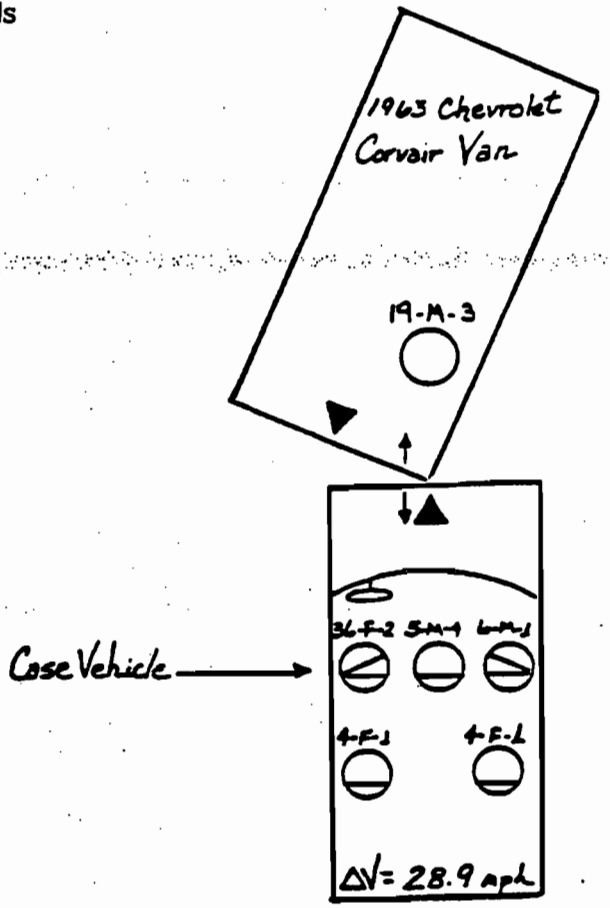
In riding down the impact forces, this occupant jackknifed violently. Her head injury was probably brought about by violent contact with her own right leg. This contact probably was intensified by the continuing travel into the semi-rigid rear surface of the driver's seat. The interior dimensions of the left rear passenger compartment were not great enough, even with the driver's seat adjusted fully forward, to avoid a contact by a person of her size. The forward displacement of the driver's seatback is evidence of that contact.

It is difficult to assess the probabilities of injury if this woman had not been restrained. There were no apparent internal injuries resulting from the lap belt. However, her head injury due to the jackknifing motion would probably not have occurred without the lap belt. If the lap belt had not restrained the lower body, a force dissipation would have occurred over her face, torso, and knees. There would also have been additional forward forces placed on the seatback, probably increasing the severity of injuries sustained by the driver. In short, the rear occupant, if unbelted, might have sustained less severe injuries at the expense of the driver.

Of course, the risk of loading the driver would be eliminated if the rear occupant were lap/shoulders belted, as would the occurrence of her several head and facial injuries due to jackknifing over the lap belt.

CASE 13 (SEA-85-H-OR20)

Case vehicle: 1978 Buick Estate station wagon
Case vehicle weight: 4,570 pounds
Case vehicle Delta V: 28.9 mph



Circumstances

A 1978 Buick Estate station wagon was struck in the front, slightly left of center, by the left front corner of a 1963 Chevrolet van. The Buick was occupied by a lap/shoulder belted 36-year-old female driver, a lap belted 5-year-old boy at center front, a 6-year-old boy wearing a lap/shoulder belt at right front, and two 4-year-old girls seated in the left and right rear seats, restrained by lap belts. The force of this head-on collision destroyed the front structures of both vehicles.

This accident resulted in moderate injuries to the Buick driver, serious injury to the lap belted boy in the center front, and minor to moderate injuries to the children seated right front, left rear, and right rear. The unrestrained 19-year-old man driving the van, who had fallen to the floor before the impact, received multiple fractures of his left leg and required extensive medical care.

Restraint and Injury

Seating location: Driver
Sex: F
Age: 36
Height: 5 feet 2 inches
Weight: 155
Seated height: 33 inches
Restraint used: Lap/shoulder belt
Proper use? Possible slack in shoulder belt

This driver was wearing a 3-point, continuous loop, lap/shoulder belt that incorporated an emergency locking retractor, cinching type of latchplate, and a pushbutton release type of buckle mounted to a flexible plastic stalk. A windowshade type of tension relief device also was incorporated into this restraint system.

The Safety Board investigation did not note loading marks on the system webbing at this position. The A pillar, instrument panel, and steering assembly were displaced several inches rearward. The steering column was broken, and the hub and wheel were displaced several inches outboard. The A pillar, deformed rearward approximately 6 inches at its base, had hair embedded around a trim mounting screw located on its interior side. The driver's portion of the split bench seat was found at its extreme forward adjustment on a 7-inch track.

The driver related that her lap belt was positioned low across her hips with "snug" tension, but could not give information concerning the adjustment or positioning of her shoulder strap.

Injuries	AIS	Probable Source
Closed head injury with unspecified loss of consciousness	2	A pillar
Major contusions, right and left eyes	2	Steering rim and A pillar
Lacerations with embedded glass, scalp	1	Windshield
Laceration, forehead	1	Steering rim or A pillar
Contusion (10-cm diameter), chest	2	Steering assembly
Contusion, right forearm	1	Steering assembly
Contusion, left forearm	1	Steering assembly
Contusion, left shoulder	1	Interior sidewall
Laceration, lower right leg	1	Below instrument panel

This woman was treated at a local hospital and released after several hours of observation required for the head injury. She required followup care by her personal doctor, but fully recovered from all injuries.

The driver's lap/shoulder belt did not prevent upper body contact with the vehicle interior, due to the driver's frontal compartment rearward displacement. When the distance of her head travel into the A pillar is considered, it appears that there was excess slack in the shoulder belt, possibly due to the "windowshade" device. The absence of pelvic, femur, and knee injuries (from the collapsed instrument panel) indicates that some amount of restraint was provided by the lap belt portion of the system. The use of the restraint system probably prevented a more severe level of injuries.

Seating location: Center front
Sex: M
Age: 5 1/2
Height: 40 inches
Weight: 52
Seated height: 23 inches
Restraint used: Lap belt (static)
Proper use? Probably

This child was wearing a static lap belt at the time of the collision. It had a pushbutton release type of buckle mounted to a 6 1/2-inch length of webbing which entered the seating area through the lower seat cushion, and a cinching type of latchplate adjustable on a 43-inch length of webbing.

The top front surface of the cushioned instrument panel, just to the left of this position's approximate longitudinal center, was indented. The entire instrument panel forward of this position was pushed rearward due to compression of the frontal structure.

Injuries	AIS	Probable Source
Le Fort III maxilla fracture	4	Instrument panel
Le Fort II fracture	3	Instrument panel
Fractured nose	1	Instrument panel
Basilar skull fracture with cerebrospinal fluid leak	4	Instrument panel
Laceration to forehead	1	Instrument panel
Minor contusion, face	2	Instrument panel

This child spent 9 days in the hospital.

The evidence presented by this child's injuries and the vehicle interior damage in his vicinity suggests that the major deceleration took place as his head hit the instrument panel, with little deceleration occurring at the lap belt level. If he had not been wearing the lap belt, he would have sustained at least moderate injuries, since his body would have been thrown into the instrument panel. However, the severe head and face injuries that he in fact sustained were due to the jackknifing action induced by the lap belt, that accelerated his face into instrument panel and concentrated much of the forces on this small part of his body.

It is useful to compare the experience of this small child seated center front, lap belted, in a Delta V 28.9 mph crash inside a 4,500-pound large car, with the experience of the small child seated center front, unrestrained, in a Delta V 28.6 mph crash inside a 4,000-pound large car (Case 34). The unrestrained child rode down the crash forces by decelerating against the instrument panel with much of her body; she sustained only moderate injuries to her vulnerable head, although she sustained AIS 2 and 3 level injuries to her left leg. The small boy, on the other hand, lap belted, sustained one AIS 2 level injury, one AIS 3 level injury, and two AIS 4 level injuries, all to his face and head.

All things considered, the Safety Board concludes that this boy would likely have been better off unrestrained in this crash than wearing a lap belt with no upper torso restraint. If he could have been restrained in a lap/shoulder belt (not available at the center front position), he probably would have received only minor abrasions and/or contusions. Compare, for example, the injuries sustained by the boy of similar size seated next to him with a lap/shoulder belt: minor belt abrasions and an AIS 1 (minor) bump on his head.

Seating location: Right front
Sex: M
Age: 6
Height: 44 inches
Weight: 40
Seated height: 24 1/2 inches
Restraint used: Lap/shoulder belt
Proper use? Yes

This child was wearing a lap/shoulder belt similar to the driver's. There was no evidence of force loading scars recovered during the Safety Board investigation and no interior compartment distortion was noted. The seat was found adjusted to 3 inches from extreme forward on a 7-inch track.

Injuries	AIS	Probable Source
Minor lacerations at hairline	1	Broken glass
Abrasion, right shoulder	1	Shoulder strap
Abrasion, across abdomen	1	Lap belt
Small bump on head	1	Interior sidewall

This passenger was treated and released at a local clinic with a note at dismissal to contact the doctor if any abdominal complications developed. No complications were found during a followup interview 3 months after the crash.

Seating location: Left rear
Sex: F
Age: 4
Height: 41 inches
Weight: 40
Seated height: 23 inches
Restraint used: Lap belt (ALR)
Proper use? Yes

This girl was restrained by a lap belt with an automatic locking retractor, a latchplate sewn in to the end of a 35-inch length of retractable webbing, and a pushbutton release type of buckle attached to an 8-inch length of webbing. Both the latchplate webbing and the buckle webbing entered the seating area through the junction of the upper and lower seat cushions. There was no evidence of restraint use noted from the webbing system or hardware.

The seatback cushion was displaced forward approximately 6 inches by cargo within the rear area of the station wagon. No other compartment deformation was noted. No estimate of belt adjustment was available.

Injuries	AIS	Probable Source
Lower abdominal contusion	1	Lap belt
Lower back strain	1	Lap belt
Small laceration, left cheek	1	Broken glass

The child was treated and released at an area children's hospital. No complications developed.

This child and the little girl on the right of the rear seat probably benefited tremendously from the extra wide and firm lower seat cushion installed in the full size station wagon. Although they probably jackknifed severely about the lapbelt, the firm seat would not allow the submarining likely with an unsupported lower seat cushion. Also, the wide surface of the cushion allowed the downward acceleration, around the lap belt, to be dissipated into the cushion rather than hurling the girls' heads and necks downward between their knees into the area in front of their seat. The system anchor points being well below and behind the seat cushion junction kept the belt low on the girls' hips; the automatic locking retractor maintained "snug" tension.

Seating location: Right rear
Sex: F
Age: 4
Height: 40 inches
Weight: 60
Seated height: 23 inches
Restraint used: Lap belt (ALR)
Proper use? Yes

This child was restrained by a lap belt similar to the one at the left rear. No evidence of restraint use was recovered from the belt system. The girl was reportedly wearing the lap belt low across her hips. No interior compartment deformation was noted at this position.

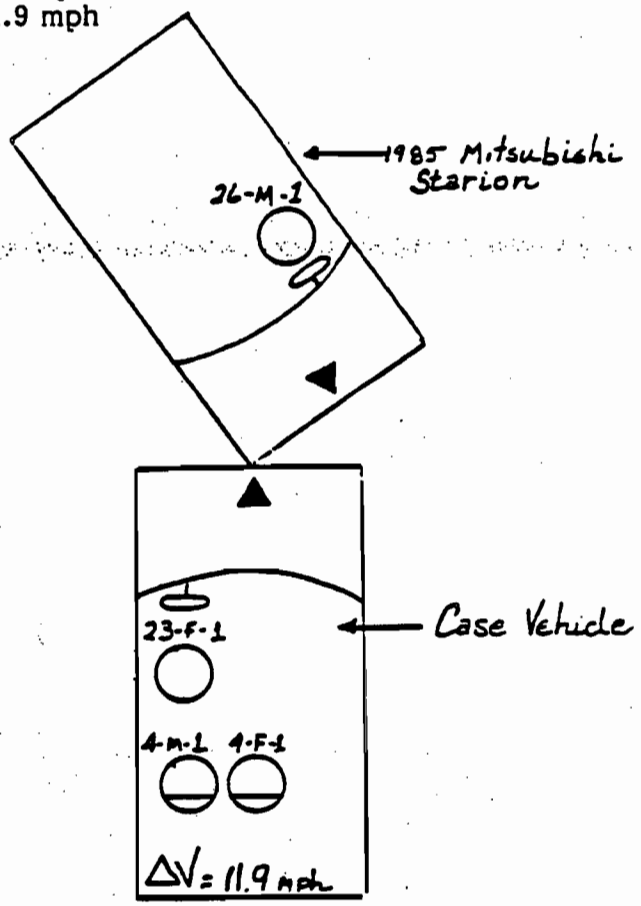
Injuries	AIS	Probable Source
Abdominal abrasions	1	Lap belt

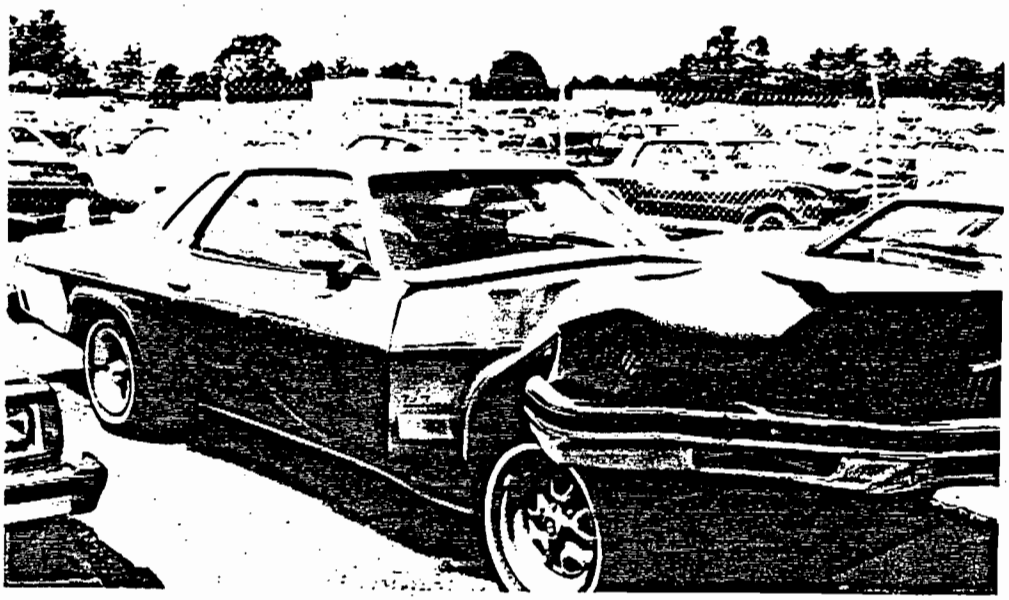
This child was treated and released at a local clinic. The doctor specifically noted that there was no evidence of abdominal injury but cautioned to watch for later evidence of internal injury. A followup interview 3 months after the accident revealed no complications of the injury.

(See comments on the left rear position, above.)

CASE 14 (ATL-85-H-OR19)

Case vehicle: 1975 Oldsmobile Cutlass
Case vehicle weight: 3,964 pounds
Case vehicle Delta V: 11.9 mph





Circumstances

A 1975 Oldsmobile Cutlass struck, center front, the right front corner of a 1985 Mitsubishi Starion turning in front of the Cutlass. The Cutlass was driven by an unrestrained 23-year-old woman; 4-year-old twins occupied the left rear and center rear seating positions, both restrained by lap belts. Both vehicles received front structural damage which necessitated towaway removal.

This collision resulted in minor injuries to the Cutlass driver and minor injuries to the lap belted 4-year-old rear seat occupants. The unrestrained driver of the Mitsubishi sustained minor to moderate injuries.

Restraint and Injury

Seating location: Driver
Sex: F
Age: 23
Height: 5 feet 4 inches
Weight: 115
Restraint used: None
Proper use? NA

This driver was not wearing the lap/shoulder belt at her seating position. There was no interior compartment compression. The entire steering assembly was displaced approximately 1 inch toward the left.

Injuries	AIS	Probable Source
Contusion, upper forehead	1	A pillar
Contusion, right jaw	1	Steering wheel rim
Abrasion, minor avulsion, right hip	1	Steering wheel rim
Contusion, left knee	1	Instrument panel

The woman did not seek medical attention on the day of the accident, but visited a local clinic approximately 2 weeks later. No followup care was required and no loss of work resulted.

Had she been wearing the available lap/shoulder belt, properly routed and tensioned, she probably would not have made the contacts with the vehicle interior. Considering the low Delta V, she probably could have decelerated into the restraint webbing without injury.

Seating location: Left rear
Sex: M
Age: 4
Height: 41 inches
Weight: 39
Seated height: 20 inches
Restraint used: Lap belt (ALR)
Proper use? Yes

This boy was wearing a lap belt with an ALR, a latchplate sewn in to the retractor webbing, and a pushbutton release type of buckle attached to a short length of webbing. Both the latchplate webbing and the buckle webbing entered the seating area by passing between the junction of the upper and lower seat cushions.

Injuries	AIS	Probable Source
Contusion, center forehead	1	Lower extremities

The investigating police officer's report indicates that this passenger received a visible injury but did not require emergency transport from the accident scene. The child's mother said no medical attention was sought until approximately 2 weeks after the crash. That visit was due to concern about the forehead contusion. Followup investigation revealed no complications of the injury.

The lap belt worn by this little boy restrained his forward movement without complications. However, the boy's lack of injury--belt induced or otherwise--is not suprising, given the low Delta V in this case. If the boy had been unrestrained, he would likely have moved forward into the rear surface of the seatback and it would not expected to see a great difference in the level of his injuries in that case from those he ... fact experienced. The vertical direction of the force line should not be expected to launch him up and over the back of the front seats, even if the Delta V had been much greater.

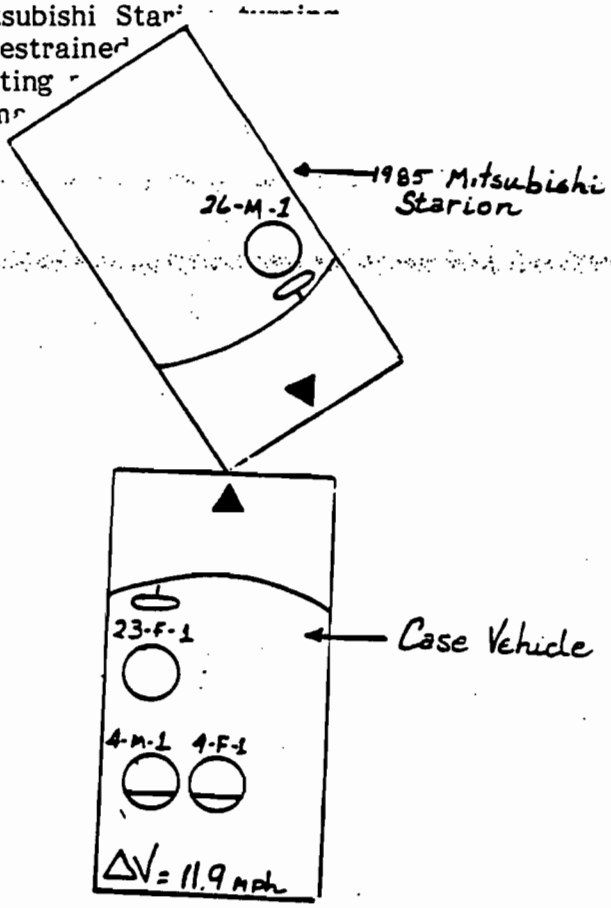
Seating location: Center rear
Sex: F
Age: 4
Height: 40 inches
Weight: 37
Seated height: 20 inches
Restraint used: Lap belt (static)
Proper use? Yes

This child was wearing a static lap belt with a pushbutton release type of buckle attached to short length of webbing and a cinching type of latchplate that was adjustable on a length of webbing. Both the buckle webbing and the latchplate webbing entered the seating area by passing between the junction of the upper and lower seat cushions. There was no interior deformation at this seating position.

Injuries	AIS	Probable Source
Contusion, lower right abdomen	1	Lap belt hardware

Circumstances

A 1975 Oldsmobile (struck, center front, the right front corner of a 1985 Mitsubishi Star Cutlass. The Cutlass was driven by an unrestrained left rear and center rear seating received front structural dam



ver and minor injuries to l driver of the Mitsubishi

eating position. There was assembly was displaced

Probable Source

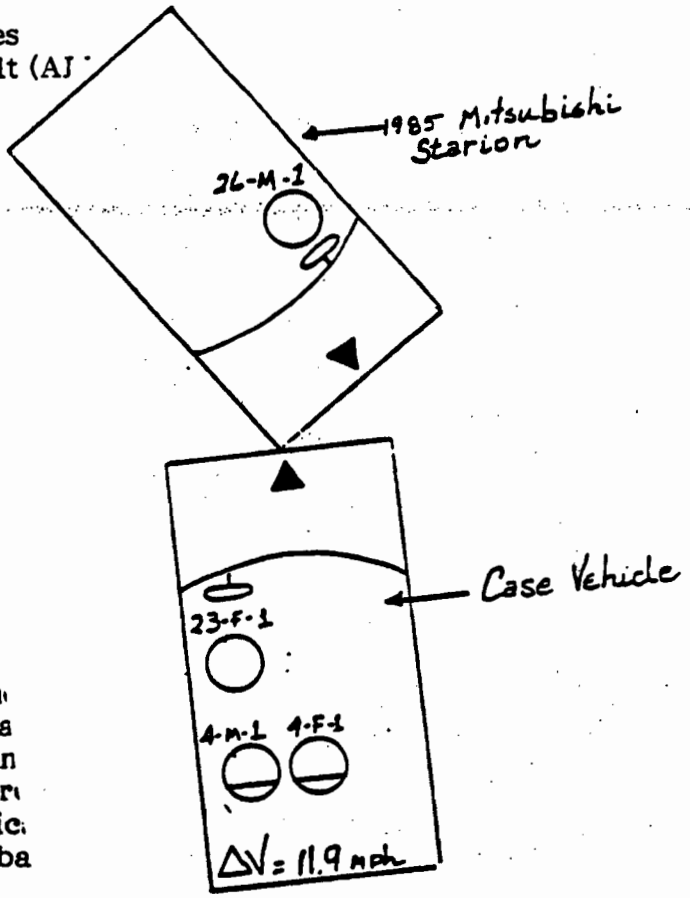
A pillar
Steering wheel rim
Steering wheel rim
Instrument panel

Contusion,

The woman did not seek medical attention on the day of the accident, but visited a local clinic approximately 2 weeks later. No followup care was required and no loss of work resulted.

Had she been wearing the available lap/shoulder belt, properly routed and tensioned, she probably would not have made the contacts with the vehicle interior. Considering the low Delta V, she probably could have decelerated into the restraint webbing without injury.

Seating location: Left rear
Sex: M
Age: 4
Height: 41 inches
Weight: 39
Seated height: 20 inches
Restraint used: Lap belt (AI
Proper use? Yes



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Injuries

Contusion, center fore

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child's mother said no medic
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investigation revealed no con

The lap belt worn by
complications. However, th
suprising, given the low Delta
likely have moved forward in
expected to see a great differ
fact experienced. The vertic
launch him up and over the ba
greater.

Seating location: Center rear
Sex: F
Age: 4
Height: 40 inches
Weight: 37
Seated height: 20 inches
Restraint used: Lap belt (static)
Proper use? Yes

This child was wearing a static lap belt with a pushbutton release type of buckle attached to short length of webbing and a cinching type of latchplate that was adjustable on a length of webbing. Both the buckle webbing and the latchplate webbing entered the seating area by passing between the junction of the upper and lower seat cushions. There was no interior deformation at this seating position.

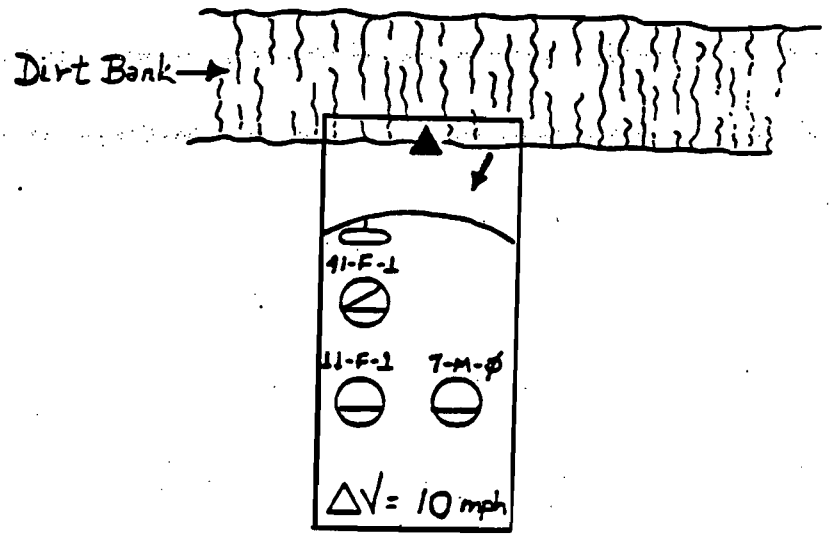
Injuries	AIS	Probable Source
Contusion, lower right abdomen	1	Lap belt hardware

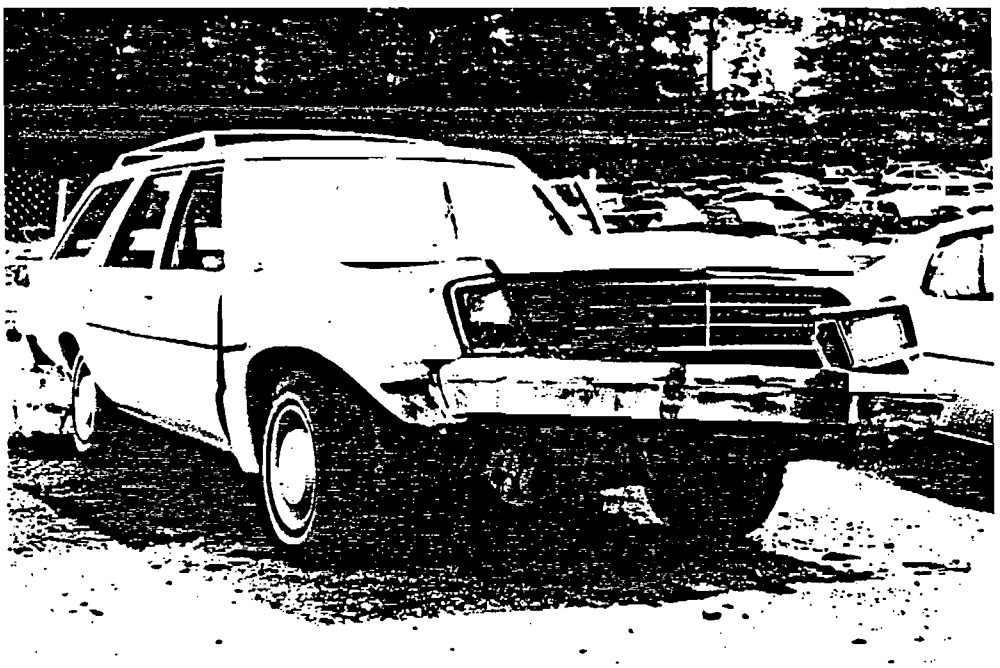
This girl did not require medical attention at any time following the accident. Followup investigation revealed that no complications resulted from the abdominal contusion.

The analysis in this girl's situation is similar to that of her brother. If she had been unrestrained, however, she might have experienced slightly more serious injuries, since the back of the front seat was split in front of her, not solid as it was in front of her brother seated extreme left. Given the angular force line (-30°) in this impact, an unrestrained child probably would have decelerated into the unbroken rear surface of the driver's seatback, but if the force line had been from straight head-on, she might have experienced head and upper chest injuries due to the 8-inch wide split in the seatback immediately in front of her. However, with the low Delta V, those injuries would still have been only minor to possibly moderate.

CASE 15 (ATL-84-H-OR28)

Case vehicle: 1980 Ford Fairmont station wagon
Case vehicle weight: 3,338 pounds
Case vehicle Delta V: 10 mph





Circumstances

A 1980 Ford Fairmont station wagon struck a dirt embankment. Substantial damage resulted and towaway removal was required. The driver was a 41-year-old woman, restrained by a lap/shoulder belt; the left rear seat was occupied by an 11-year-old girl; a 7-year-old boy was seated right rear. Both rear seat occupants were restrained by lap belts.

This accident resulted in minor injuries to the driver of the Ford and to the left rear passenger. The right rear passenger was not injured.

Restraint and Injury

Seating location: Driver
Sex: F
Age: 41
Height: 5 feet 4 inches
Weight: 125
Seated height: 26 inches
Restraint used: Lap/shoulder belt (ELR)
Proper use? No

The driver was restrained by a 3-point, continuous loop, lap/shoulder belt with an ELR sensitive to vehicle motion, a cinching type of latchplate, and a pushbutton release type of buckle. The buckle was attached to a flexible stalk that entered the seating area by passing through the lower seat cushion at the junction of the upper and lower cushions. No evidence of force loading was found on the system webbing. The windshield-mounted rear view mirror was broken from its pre-crash position. The lower area of the instrument panel, just inboard of the steering column, was damaged.

Injuries	AIS	Probable Source
Small laceration, right forehead	1	Rearview mirror
Abrasion, right forehead	1	Rearview mirror
Contusion, mid-sternum	1	Steering wheel rim
Contusion, lower right leg	1	Lower instrument panel

She was treated and released at a local hospital.

This woman told Safety Board investigators that the pre-crash adjustment of her lap/shoulder belt was "snug," with the lap belt portion low on her hips and the shoulder strap across her chest mid-sternum. However, the evidence indicates that either she was wearing her restraint with excessive slack or the retractor did not lock. Given her seated height, it was not possible for her to have struck the rearview mirror while remaining within a "snugged up" shoulder strap. Also, the "deep bruise" on her mid-sternum area is not the type of injury received from restraint webbing. The "deep" contusion would be expected from contact with the steering wheel rim. This accident's impact was simply not severe enough to result in much webbing stretch or more than just a few inches of travel within the webbing system. The Board concluded that the restraint was not being worn properly--that is, there was excessive slack in the system that was quite possibly the result of improper "windowshade" adjustment.

Seating location: Left rear
Sex: F
Age: 11
Height: 4 feet 8 inches
Weight: 85
Seated height: 23 inches
Restraint used: Lap belt (ALR)
Proper use? Yes

This child was restrained by a lap belt with an ALR, a latchplate sewn in to the 33-inch-long retractable webbing, and a pushbutton release type of buckle mounted to a short length of webbing. Both the latchplate and buckle webbing entered the seating area from between the junction of the upper and lower seat cushions. There was no interior compartment deformation at this seating position.

Injuries	AIS	Probable Source
Contusion, center forehead	1	Lower extremity
Contusion, lower right thigh	1	Right elbow

This child was treated and released at a local hospital. Her mother said that no school time was lost as a result of the accident.

(See discussion at end of this case summary.)

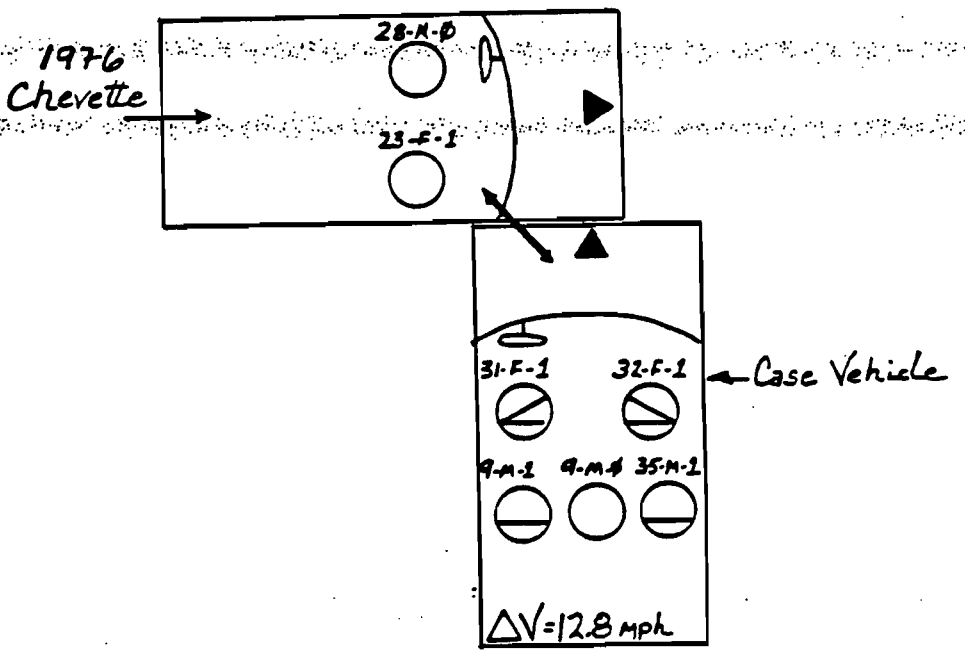
Seating location: Right rear
Sex: M
Age: 7
Height: 40 inches"
Weight: 40
Seated height: 18 inches
Restraint used: Lap belt (ALR)
Proper use? Yes

This child was wearing a lap belt similar to his sister's. There was no compartment deformation at this seating position. He was checked at a local hospital and released with no reported injuries.

Considering the relatively low Delta V of only 10 mph, the use of the lap belts by these children probably had little effect on injury. Had the children not been restrained, they would have been decelerated by the rear surface of the front bench seatbacks, a "containment" surface found to be an "occupant friendly" contact point in several cases with similar and higher crash forces.

CASE 16 (MKC-85-H-OR26)

Case vehicle: 1980 Ford Subaru GL station wagon
Case vehicle weight: 3,111 pounds
Case vehicle Delta V: 12.8 mph



Circumstances

A 1980 Subaru station wagon struck a 1976 Chevette in the front right side. The Delta V for the Subaru was 12.8 mph. It was driven by a 31-year-old woman restrained by a lap/shoulder belt. Other occupants of the Subaru included a 32-year-old woman seated right front wearing a lap/shoulder belt, a lap belt restrained 9-year-old boy seated left rear, a 35-year-old man seated right rear wearing a lap belt, and a 9-year-old boy seated center rear unrestrained. The impact substantially damaged both vehicles and both required towaway.

This accident resulted in minor injury to the Subaru driver, right front passenger, left rear passenger, and right rear passenger. The unrestrained center rear passenger was not injured. The Chevette right front passenger, an unrestrained 23-year-old woman, received minor injuries; the driver, an unrestrained 28-year-old man, was without reported injury.

In this case of low Delta V, little difference in injury levels is seen between the restrained and unrestrained occupants.

Restraint and Injury

Seating location: Driver
Sex: F
Age: 31
Height: 5 feet 7 inches
Weight: 130
Restraint used: Lap/shoulder belt (ELR)
Proper use? Yes

This driver was restrained by a 3-point, continuous loop, lap/shoulder belt with an ELR sensitive to webbing acceleration, a free-sliding latchplate, and a pushbutton release type of buckle mounted to a flexible stalk. A "comfort clip" was attached to the webbing as a tension relief device.

There was no interior deformation at he seating compartment and no indication of force loading scars on the belt webbing. The driver said she had adjusted her seat to the middle of its track. This adjustment position was confirmed at 3 1/2 inches from forwardmost on a 6 1/2-inch track.

Injuries	AIS	Probable Source
Small laceration, right hand	1	Broken sideglass from vehicle 2
Contusion, inside left knee	1	Steering column

This woman reportedly refused medical treatment for the minor injuries sustained in the collision.

Seating location: Right front
Sex: F
Age: 32
Height: 5 feet 6 inches
Weight: 200
Restraint used: Lap/shoulder belt
Proper use? Yes

This woman was restrained by a lap/shoulder belt similar to the driver's. Again, there was no interior compartment deformation at this seating position. This passenger seat was found adjusted to a position 3 1/2 inches from forwardmost on a 6 1/2-inch track.

Injuries	AIS	Probable Source
Contusion, right hip	1	Lap belt

This woman reportedly refused medical treatment of her minor injury.

Seating location: Left rear
Sex: M
Age: 9
Height: 4 feet 6 inches
Weight: 73
Restraint used: Lap belt (ELR)
Proper use? Yes

This boy was restrained by a lap belt with an ELR sensitive to webbing acceleration, a latchplate sewn in to the retractor webbing, and a pushbutton release type of buckle attached to a short length of webbing. Both the latchplate webbing and the buckle webbing entered the seating area by passing between the junction of the upper and lower seat cushions. There was no compartment deformation at this seating position nor any evidence of force loading on the webbing system.

Injuries	AIS	Probable Source
Small laceration, right rear of head	1	Wristwatch worn by right rear passenger

This boy reportedly refused medical treatment.

Seating location: Center rear
Sex: M
Age: 9
Height: 4 feet 7 inches
Weight: 68
Restraint used: None
Proper use? NA

This boy was riding unrestrained at center rear. The owner and driver of the Subaru was reportedly unaware that a static lap belt was installed at the position but tucked under the lower seat cushion.

There was no compartment deformation noted at this position and no injuries were reported by the occupant.

Seating location: Right rear
Sex: M
Age: 35
Height: 5 feet 6 inches
Weight: 185
Restraint used: Lap belt (ELR)
Proper use? Yes

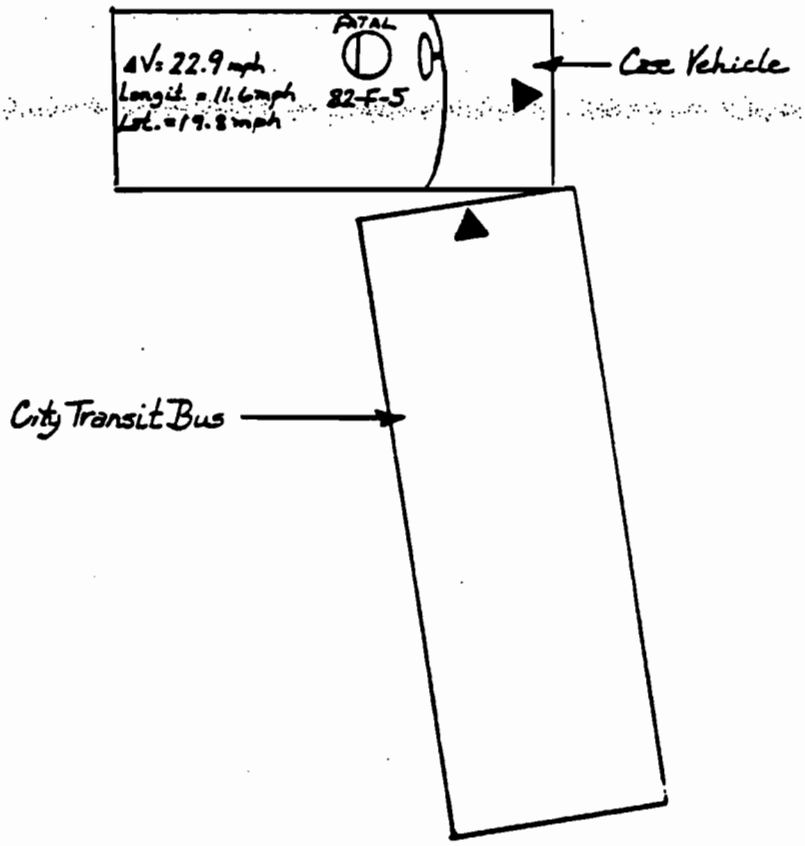
This man was wearing a lap belt similar to the one on the left. There was no evidence of interior compartment deformation nor force loading marks on the system webbing. This occupant was reportedly riding with his left arm extended and lying on the uppermost surface of the rear seatback. The wristwatch worn on his left arm was the source of minor laceration the left rear passenger's head.

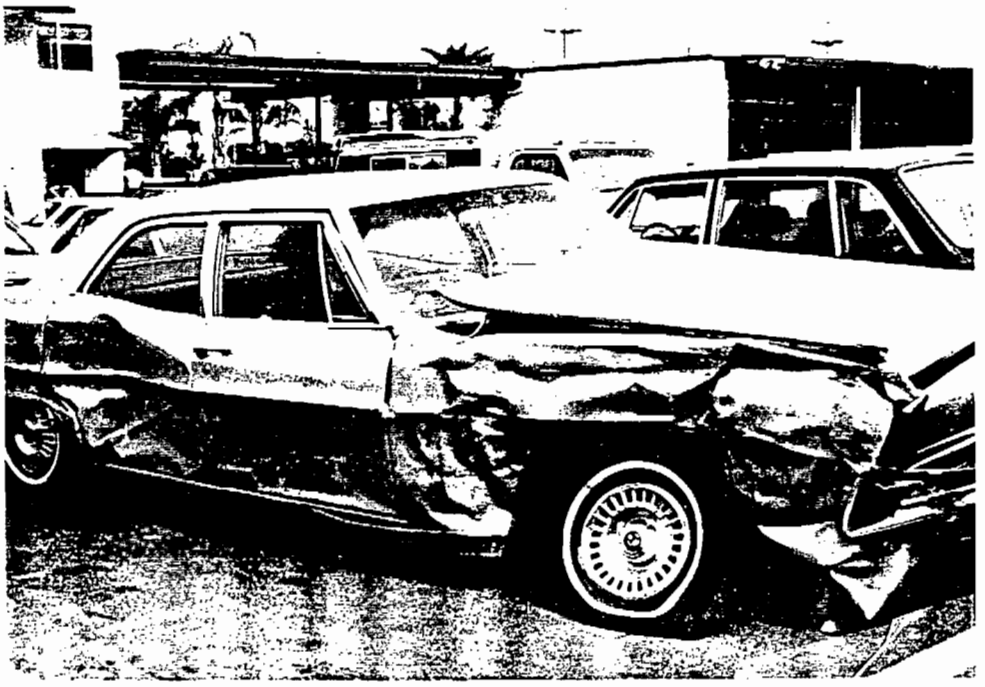
Injuries	AIS	Probable Source
Sprained left thumb	1	Rear of front seat

This man reportedly refused treatment for his minor injury.

CASE 17 (LAX-85-H-OR18)

Case vehicle: 1967 Pontiac Catalina, 4-door
Case vehicle weight: 4,250 pounds
Case vehicle Delta V: 22.9 mph





Circumstances

A 1967 Pontiac was struck on the right front side by a city bus. The Pontiac was being driven by an 82-year-old woman who was restrained by a static lap belt. The Pontiac received substantial structural damage along its right side; there was no apparent compartment distortion at the driver's position.

This accident resulted in severe to critical intra-abdominal injuries to the driver of the Pontiac which proved fatal approximately 36 hours after the crash. The injuries were lap belt induced.

Restraint and Injury

Seating location: Driver
Sex: F
Age: 82
Height: 5 feet 1 inch
Weight: 150
Seated height: 33 inches
Restraint used: Lap belt (static)
Proper use? Yes

Injuries	AIS	Probable Source
Multiple through-and-through tears in mesentery	4	Lap belt
Perforation (15 mm) of bowel	5	Lap belt
Major contusion, abdomen	2	Lap belt
Contusions, both feet	1	Foot controls
Contusion, upper right arm	1	Cargo

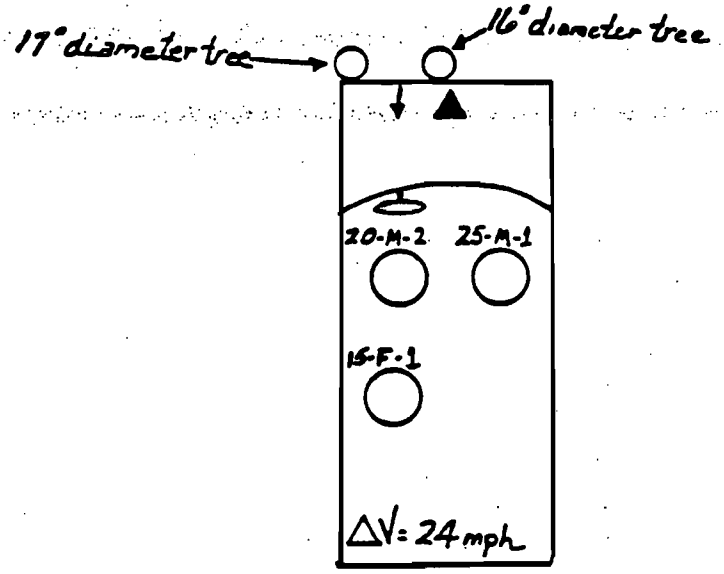
This case dramatically illustrates the fact that, contrary to widely-expressed views in the literature, a severe impact is not necessary to induce severe, even fatal, injuries in lap belt-restrained occupants (see, among others, Cases 6, 8, 9, 23, 25, and 27). In this case, the major area of belt loading was on the extreme right side of her abdomen--not surprising, given that the major crash forces came into play at approximately 70° to 80° into the right front side of the Pontiac. Given the crash configuration, it could also be expected that a shoulder strap might not have prevented either the type or severity of intra-abdominal injury, because she might well have traveled out from behind the shoulder strap in this crash. (Federal safety standards for passive belt systems, the only systems covered by dynamic testing standards, require protection only in crashes within 30° of straight head-on).

This case is also important as an illustration of the sorts of postcrash medical handling deficiencies discussed in Baker and others. The hospital records here seem to reflect a lack of familiarity with the extent of intra-abdominal trauma possible with lap belts. Strong symptoms of the woman's massive injuries were apparently not obvious for at least several hours after the crash. Medical personnel did keep a fairly close watch on the woman's blood pressure; but when it dropped, a symptom also accompanied by onset of rapid pulse, about 28 hours after the crash, no action was taken for several hours.

Internal X-rays were not taken for close to 3 hours, and then only after a second lapse in blood pressure at 8 p.m. An exploratory laparotomy was then planned, but within 25 minutes of the X-rays (while on the operating table), the woman died. Death was officially attributed to aspiration of gastric contents, due to generalized peritonitis from a ruptured bowel with mesenteric lacerations.

CASE 18 (SEA-85-H-OR25)

Case vehicle: 1980 Toyota Celica 2-door
Case vehicle weight: 2,885 pounds
Case vehicle Delta V: 24 mph



Circumstances

A 1980 Toyota Celica struck, head-on, two trees 16 to 17 inches in diameter. The impact resulted in substantial damage to the front structure of the vehicle, with rearward collapse reaching a depth of 26 inches at the front center point of impact. The vehicle was occupied by a 20-year-old male driver, a 25-year-old male right front passenger, and a 15-year-old female seated left rear. There were no restraints being used by these occupants.

This accident resulted in moderate injuries to the driver and minor to moderate injuries to the right front passenger. The left rear passenger sustained only minor abrasions attributed to contact with the rear surface and framework of the driver's seatback. All occupants were transported by ambulance to an area hospital, but only the front seat occupants required emergency room treatment before being released.

Restraint and Injury

Seating location: Driver
Sex: M
Age: 20
Height: 6 feet
Weight: 170
Restraint used: None
Proper use? NA

This driver was not wearing the available 3-point lap/shoulder belt furnished at his seating position. The steering column was deformed upward several inches. The wheel was displaced forward from its 6 o'clock to 1 o'clock position, and the lower instrument panel was broken, with substantial displacement of various components.

Injuries	AIS	Probable Source
Laceration (6 cm deep), left forehead	2	Windshield
Small lacerations (two), above right eye	1	Windshield
Unspecified left abdominal injury	7	Steering assembly
Contusion, left knee	1	Lower instrument panel
Laceration (2 inch), right lower leg	1	Lower instrument panel

This man required 2 days of hospitalization. Due to a continuing complaint of abdominal pain, treating physicians performed an exploratory abdominal paracentesis to determine if there were intra-abdominal ruptures or lacerations, and found none.

Seating location: Right front
Sex: M
Age: 25
Height: 5 feet 11 inches
Weight: 165
Restraint used: None
Proper use? NA

This man was not wearing the available 3-point lap/shoulder restraint provided at his position. There was substantial distortion of the instrument panel directly forward of this seating position. There was no apparent contact damage to the windshield directly forward of this seat position.

Injuries	AIS	Probable Source
Back strain	1	Impact forces
Laceration (8 cm), left knee	1	Instrument panel
Unspecified external superficial abrasions	7	Frontal interior

He was treated and released from an area hospital.

Seating location: Left rear
Sex: F
Age: 15
Height: 5 feet 5 inches
Weight: 120
Restraint used: None
Proper use? NA

Injuries	AIS	Probable Source
Abrasion, left side of face	1	Left front seatback
Abrasion, lower left leg	1	Left front seatback
Laceration, right hand	1	Instrument panel

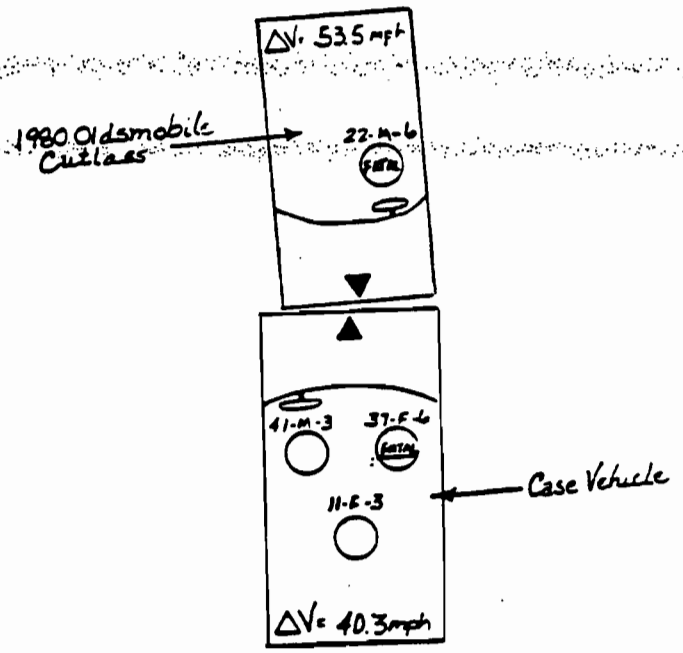
Although transported to an area hospital along with the other occupants, this girl did not require medical treatment.

This case again illustrates the potential for rear seat occupants to successfully "ride down" crash forces in situations that might well produce serious or fatal abdominal, head, and/or spinal injuries to lap belted occupants. Other cases of successful, unrestrained, rear seat "containment" can be seen in Case 4 (involving a much higher Delta V than this case), Case 7 (also involving a much higher Delta V), the unrestrained occupants of Case 23, and the occupants of the "comparison vehicle" in Case 24. The Safety Board believes that the rear seat occupant in this case might well have sustained serious head or internal/spinal injuries in this speed change of 24 mph because of the experience of similarly situated rear occupants in Cases 6, 8, 9, 10, 23, and 25.

The severity of injuries sustained by the driver in this case probably would have been reduced if he had been wearing the available lap/shoulder belt. The right front passenger probably would not have cut his knee on the instrument panel if he had worn his belt, but he probably would have sustained some level of injury due to the impact force.

CASE 19 (CHI-85-H-OR27)

Case vehicle: 1979 Dodge Ramcharger, 4-wheel drive
Case vehicle weight: 4,720 pounds
Case vehicle Delta V: 40.3 mph



Circumstances

A 1979 Dodge Ramcharger was struck head-on by a 1980 Oldsmobile Cutlass, with a resulting Delta V of 40.3 mph to the Dodge and 53.3 mph to the Cutlass. Rearward structural collapse was more than 35 inches at the right front of the Dodge; deformation at the Oldsmobile's right front exceeded 50 inches.

The unrestrained 41-year-old man driving the Dodge was seriously injured. His 37-year-old wife, seated right front restrained by a lap belt, sustained massive abdominal trauma and cervical injuries that resulted in her death. The couple's 11-year-old daughter, lying across the rear bench seat unrestrained, was seriously injured. The unrestrained 22-year-old male driver of the Oldsmobile sustained crushing chest injuries and was pronounced dead at the scene.

Restraint and Injury

Seating location: Driver
Sex: M
Age: 41
Height: 5 feet 6 inches
Weight: 150
Restraint used: None
Proper use? NA

This man was not wearing the lap belt at his position. There was extensive compartmental distortion forward of this seat position: the entire steering assembly was damaged, with forward deformation of the lower rim reaching 15 inches relative to the column hub. The entire column was collapsed forward approximately 11 inches and downward several inches. The lower instrument panel surface was distorted forward on the right and left side of the steering column.

Injuries	AIS	Probable Source
Laceration (4 inch), lower face	2	Instrument panel
Multiple contusions, face	2	Instrument panel
Unspecified head injury (amnesia)	2	Instrument panel
Multiple abrasions, face	2	Instrument panel
Fracture, left ribs 5 - 8	2	Steering assembly
Pneumothorax, left side	3	Steering assembly
Abrasion, right knee	1	Lower instrument panel
Multiple abrasions, contusions to extremities	7	Frontal interior
Contusions, left chest	2	Steering assembly

This man was in a hospital for 5 days and was unable to return to work for at least 1 month.

As in several cases investigated by the Safety Board, this man was inaccurately recorded in medical reports as having been ejected. It is virtually certain that he was not. There was no lifting force during the impact sequence that could have acted upon his body mass to bring about his ejection. The principal force was directed from the lower front of the vehicle upwards, and the driver's reactive travel would have been forward and down. This travel direction is evidenced by the forward displacement of the lower instrument

panel due to the driver's knee contact, and the forward and downward displacement of the steering assembly. With the driver's body mass concentrated lower than the steering column's principal structure, along with the forward and down reactive travel, the possibility of ejection can be ruled out. Furthermore, at maximum force exchange between the vehicles, the distorted hoods of the vehicles would have prevented his forward travel. This man probably was assisted from the car by a passerby, just as his daughter was.

Seating location: Right front
Sex: F
Age: 37
Height: 5 feet 6 inches
Weight: 185
Restraint used: Lap belt (ALR)
Proper use? Yes

This woman was wearing a lap belt with an ALR, a sewn-in latchplate attached to the retractor webbing, and a pushbutton release type of buckle mounted to a short flexible stalk. Both the retractor anchor and resultant buckle position were located well below and behind the woman's lower body mass.

There was little compartmental compression at this seating position. There was a circular depression just below the hinged glove compartment door, directly forward of the seat. Inspection of the restraint system webbing revealed a force loading scar on the retractable latchplate webbing.

Injuries	AIS	Probable Source
Multiple lacerations, left eye	2	Instrument panel and below
Contusion, left temporal lobe	2	Instrument panel and below
Translocation, 1st cervical vertebra	3	Hyperextension force
Complete transection of spinal cord at base of skull	6	Hyperextension force
Fractured sternum	2	Lower extremities contact
Major abrasion, lower abdomen	2	Lap belt
Major contusion, lower abdomen	2	Lap belt
Multiple transections, small intestine	5	Lap belt
Transection, descending aorta (small intestine)	6	Lap belt
Extensive avulsion, posterior peritoneum	5	Lap belt

This woman was found at the accident without signs of life.

This woman's internal injuries appear to have been concentrated in the area directly over the crest of the ilium and resulted from the belt's penetration into the abdominal cavity. The injury location does not indicate improper belt routing when the force line, Delta V, and resultant body travel are considered. An extremely violent jackknife

occurred as the woman's upper and lower body mass folded over the lap belt webbing. The front portion of the iliac crest is rounded; as a body jackknifes over a lap belt, the belt may also fold over, resulting in a much narrower restraining surface. As the pelvic bone, itself rounded, pushes forcefully against the folded belt webbing, there would be little resistance to the webbing riding up and over the iliac crest. This fact, combined with the force line acting on the victim's body seems to indicate that the lap belt webbing was probably routed in the area considered to be proper. Had the lap belt been routed over the mid-abdomen prior to the impact, the internal injury pattern would have been to organs located higher in the abdominal cavity.

If this passenger had been wearing a 3-point lap/shoulder belt system, the probability of survival would have been much greater. Some level of restraint-related injuries would be expected, but the violent jackknife and resultant neck hyperextension would not have occurred. The severity of her internal injuries also would have been reduced by use of a shoulder strap, due to prevention of the jackknife over the lap belt webbing.

Seating location: Rear seat
Sex: F
Age: 11
Height: 4 feet 6 inches
Weight: 70
Restraint used: None
Proper use? NA

This child was reportedly lying across the rear bench seat. There was no compartmental compression or deformation at this seating area.

Injuries	AIS	Probable Source
Fracture, upper right femur	3	Rear framework of front seat
Abrasion, chin	1	Rear framework of front seat
Major contusion, right ankle	2	Rear framework of front seat
Laceration, left upper forehead	1	Rear framework of front seat

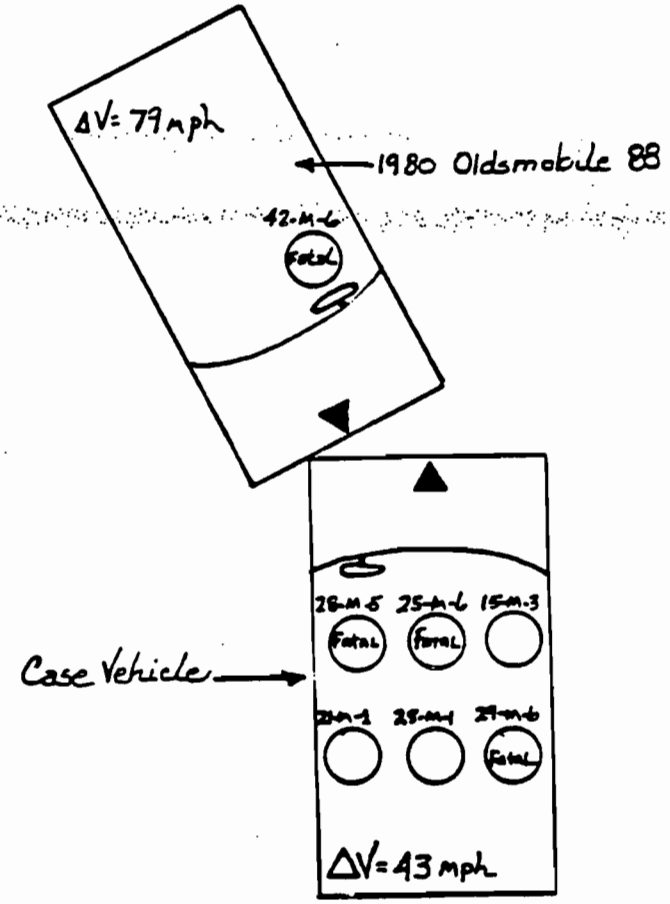
This girl spent 4 days in a local hospital.

She probably came out of this accident with as low a level of injuries as could be expected, when the high Delta V is considered. Even a fully-restrained passenger would probably have sustained moderate to serious injury in this speed change of more than 40 mph.

Certainly the types of injuries she sustained are different from those which would be expected if a restraint had been worn. If this child had been wearing a lap belt only, it would be reasonable to expect massive injuries similar to those sustained by the right front passenger. (See also the injuries sustained by 13-year-old boys, lapbelted, in Case 1, a Delta V 37 mph crash, or the lap-belted children in Cases 8, 10, and 23.)

CASE 20 (FTW-85-H-OR39)

Case vehicle: 1973 Chevrolet Impala, 4-door
Case vehicle weight: 5,200 pounds
Case vehicle Delta V: 43 mph



Circumstances

A 1973 Chevrolet Impala was struck head-on, right front to left front corner, by a 1980 Oldsmobile 88. From the area of impact, the Oldsmobile was deflected rearward approximately 14 feet from its original travel path. The Chevrolet rotated counterclockwise over 27 feet to its final resting position. Both vehicles were destroyed by the severe impact forces.

The Chevrolet was occupied by 6 males who ranged in age from 15 to 29 years. There were no restraints being used by these occupants. This collision resulted in fatal injuries to the unrestrained driver of the Oldsmobile (a 42-year-old man), the Chevrolet driver, the Chevrolet center front passenger, and the Chevrolet right rear passenger. The right front passenger of the Chevrolet sustained serious to severe injuries and required extensive medical treatment. Both the center rear and left rear passenger of the Chevrolet received only minor contusions and abrasions.

Restraint and Injury (Chevrolet)

Seating location: Driver
Sex: M
Age: 28
Restraint used: None
Proper use? NA

This driver was not wearing the available lap/shoulder belt. There was massive rearward distortion of the frontal interior at this seating position. The instrument panel, steering assembly, and A pillar with surrounding structure were displaced rearward into the driver, requiring extensive extrication efforts by rescue personnel.

Injuries	AIS	Probable Source
Frontal subarachnoid hemorrhage	3	Collapsed structure
Multiple lacerations to liver	5	Steering assembly
Lacerations to abdominal wall	5	Steering assembly
Torn aorta	5	Steering assembly forces
Contused lungs	4	Steering assembly forces
Fractured pelvis	2	Collapsed structure
Fractured left radius	2	Collapsed structure
Fractured right fibula	2	Collapsed structure
Fractured right tibia	2	Collapsed structure

This man died after 12 days of intensive care provided at an area hospital.

This severe collision was not survivable for either driver. The fact that the Chevrolet driver lived 12 days was due only to the intensive efforts of medical personnel. Even if he had been wearing the available lap/shoulder belt, the frontal interior would still have collapsed rearward into his body. The fact that the left rear passenger was not restrained probably increased the severity of this driver's massive chest injuries, as the seatback was loaded and pushed forward in opposition to the impact forces. However, even without this additional seatback loading, this man would have received the critical internal injuries due to the crushing deformation of the frontal interior.

Seating location: Center front
Sex: M
Age: 25
Height: 5 feet 3 inches
Weight: 152
Restraint used: None
Proper use? NA

This occupant was not wearing the static lap belt available at his seating position. There was moderate rearward displacement of the forward compartment at this position.

Injuries	AIS	Probable Source
Facial abrasions	1	Instrument panel and windshield
Massively crushed chest (upper)	6	Instrument panel
Laceration of aorta	5	Instrument panel
Laceration, liver	4	Instrument panel
Bilateral pulmonary contusion	4	Instrument panel
Multiple contusions and abrasions	7	Frontal interior

This occupant died as a result of his injuries.

Had some type of upper and lower body restraint been available to, and used by, this man, it is possible he would have survived. However, given the high Delta V, he would still have been susceptible to serious, restraint induced injuries and other injuries.

Seating location: Right front
Sex: M
Age: 15
Restraint used: None
Proper use? NA

This passenger was not wearing the lap/shoulder restraint available at his position.

Injuries	AIS	Probable Source
Fracture, left jaw	2	Instrument panel and A pillar
Fracture, right jaw	2	Instrument panel and A pillar
LeFort II fracture	3	Instrument panel and A pillar
Laceration, lower lip	1	Instrument panel and A pillar
Fracture, left side 1st rib	1	Instrument panel and A pillar
Abrasion, left flank	1	Instrument panel
Large contusion, front lower left leg	2	Instrument panel and below
Large contusion, front lower right leg	2	Instrument panel and below
Closed displaced fracture, left pelvis	3	Instrument panel and below
Displaced fracture, left 6th rib	2	Instrument panel and below
Multiple contusions and abrasions	7	Instrument panel and below

This boy received extensive medical treatment for 11 days before being discharged to outpatient care.

If this boy had used the lap/shoulder belt, he probably would have avoided his serious facial injuries, or at least they would have been less severe. However, like the other front seat occupants in this severe impact, he would have been susceptible to serious injuries, belt induced and otherwise.

Seating location: Left rear
Sex: M
Age: 22
Restraint used: None
Proper use? NA

This man was not wearing the available lap belt. There seems to have been little forward distortion of the rear surface of the front seatback directly forward of this passenger's position. It should be noted, however, that the driver's body was compressed rearward into the seatback, due to the collapse of the front interior and steering assembly.

Injuries	AIS	Probable Source
Multiple contusions and abrasions	1	Front seatback

This passenger was treated and released at a local hospital.

Seating location: Center rear
Sex: M
Age: 28
Restraint used: None
Proper use? NA

This passenger was not wearing the static lap belt available at his seat position. There was moderate to severe forward distortion of the front seatback cushion directly in front and toward the right of this seat position.

Emergency medical technicians said that this passenger was taken to an area hospital with minor contusions and abrasions. Hospital officials said that he must have refused treatment, since the hospital has no record of him.

Injuries	AIS	Probable Source
Multiple contusions and abrasions	1	Front seatback

The survival, with only minor injuries, of the left and center rear passengers was due to the containment provided by the rear surface of the front seatback. (See Cases 4, 18, 23, and 24.)

Seating location: Right rear
Sex: M
Age: 28
Height: 5 feet 6 inches
Weight: 138
Restraint used: None
Proper use? NA

This passenger was not wearing the available lap/shoulder belt. There was substantial forward displacement of the extreme right side of the front seatback in front of this man.

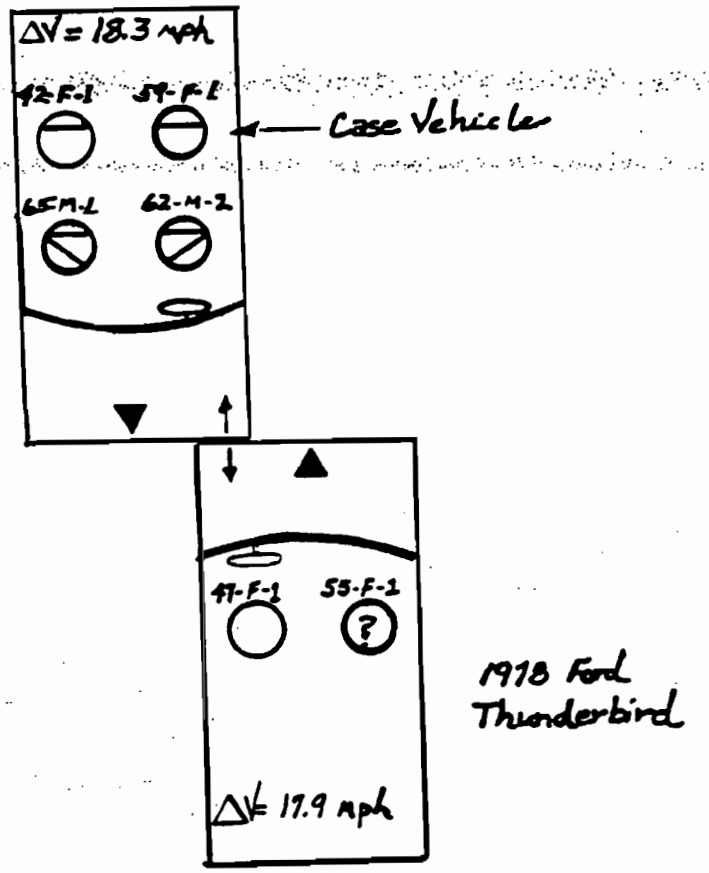
Injuries	AIS	Probable Source
Transection of aorta	6	Front seatframe and interior sidewall
Massively crushed chest	6	Front seatframe and interior sidewall
Multiple lacerations, liver	4	Front seatframe and interior sidewall
Multiple contusions, lower extremities	2	Front seatframe and interior sidewall
Multiple abrasions, lower extremities	2	Front seatframe and interior sidewall
Facial abrasions, contusions	1	Front seatframe and interior sidewall

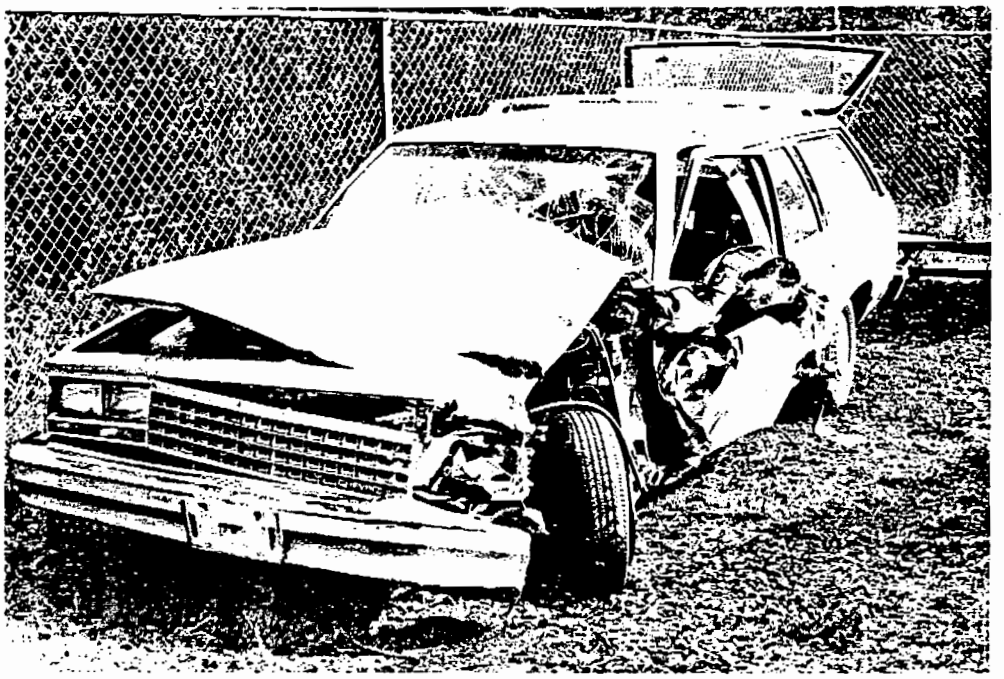
This man was pronounced dead at the accident scene; he was found wedged between the outboard edge of the front seat and right interior sidewall.

Had any of the rear occupants been restrained by the available lap belts, some level of restraint-related injuries would have resulted, due to deceleration into the 2-inch-wide webbing. With the probability of severe jackknifing over the belt and injury-producing hyperflexion. Fatal internal, spine, or head and neck injuries would have been very possible if lap belts had been used in the rear seat. The right rear passenger probably would have survived if he had been restrained in a properly fitted lap/shoulder belt.

CASE 21 (SEA-85-H-OR26)

Case vehicle: 1983 Chevrolet Malibu station wagon
Case vehicle weight: 4,258 pounds
Case vehicle Delta V: 18.3 mph





Circumstances

A 1983 Chevrolet Malibu station wagon was struck straight head-on, left front to left front, by a 1978 Ford Thunderbird. The Malibu was occupied by a lap/shoulder belt restrained 62-year-old male driver, a lap/shoulder belt restrained 65-year-old man seated right front, a lap belted 59-year-old woman seated left rear, and a lap belted 42-year-old woman seated right rear. The Thunderbird was driven by an unrestrained 47-year-old woman, accompanied by a 55-year-old woman in the right front, probably unrestrained. The Delta V for both vehicles was virtually identical at approximately 18 mph (longitudinal).

This accident resulted in moderate injuries to the Malibu driver. The remaining passengers of the Malibu sustained minor injuries. The unrestrained occupants of the Thunderbird received minor injuries.

Restraint and Injury

Seating location: Driver
Sex: M
Age: 62
Height: 5 feet 7 inches
Weight: 160
Restraint used: Lap/shoulder belt (ELR)
Proper use? Probably

This driver was wearing a 3-point, continuous loop, lap/shoulder belt with ELR, a windowshade tension relief feature, a cinching type of latchplate, and a pushbutton release type of buckle attached to a flexible stalk. The occupant described the pre-crash lap belt adjustment as snug, positioned low on his hips, but he was unable to relate the shoulder strap adjustment. There were force loading marks on the system webbing, attributed to webbing load at the D-ring. The steering assembly was displaced inboard and the instrument panel was moderately deformed.

Injuries	AIS	Probable Source
Abrasion, left forehead	1	Steering wheel rim
Sprain, right shoulder	1	Impact forces
Contusion, left elbow	1	Interior sidewall
Major contusion, right thigh	2	Steering wheel rim
Abrasion, left forearm	1	Interior sidewall
Small laceration, left hand	1	Broken side glass

This man was treated and released at a local hospital. He might have sustained serious injuries if he had been unrestrained, making violent contact with the steering assembly, A pillar, and lower instrument panel.

Seating location: Right front
Sex: M
Age: 65
Height: 5 feet 11 inches
Weight: 195
Restraint used: Lap/shoulder belt
Proper use? Unknown

This passenger was wearing a lap/shoulder belt similar to the driver's. No information concerning precrash system adjustment was furnished by this occupant. There was a force loading scar, attributed to the D-ring, on the system webbing at approximately 33 inches above the retractor. There was no compartment deformation noted forward of this seating position.

Injuries	AIS	Probable Source
Transverse fracture, 10th and 11th left ribs	1	Shoulder strap
Abrasion, left elbow	1	Right side steering wheel rim
Abrasion, left forearm	1	Right side steering wheel rim
Contusion, diagonally across chest	1	Shoulder strap
Abrasion, diagonally across chest	1	Shoulder strap
Contusion, over left iliac crest	1	Lap belt
Small laceration, lower right leg	1	Lower instrument panel

This man was treated and released at an area hospital.

Given this man's height, he probably would have received some level of facial injuries (from contacting the windshield), along with a higher level of injuries to his lower extremities, due to contacts with the lower instrument panel and below, if he had been unrestrained.

Seating location: Left rear
Sex: F
Age: 59
Height: 5 feet 6 inches
Weight: 155
Restraint used: Lap belt (ALR)
Proper use? Yes

This passenger was wearing a lap belt with an ALR, a sewn-in latchplate attached to the retractable webbing, and a pushbutton release type of buckle. The buckle was attached to an 11-inch portion of webbing which entered the seating area at the junction of the upper and lower seat cushions. This woman said that the pre-crash lap belt adjustment was "snug," with the webbing positioned low on her hips. There was no compartment deformation at this seating position.

Injuries	AIS	Probable Source
Laceration (1 cm), over left eye	1	Eyeglasses
Abrasion, lower abdomen	1	Lap belt
Contusion, lower abdomen	1	Lap belt
Contusion, around left eye	1	Front seatback

She was treated and released at an area hospital. A Safety Board followup interview revealed that she was still experiencing abdominal tenderness 1 month after the accident.

It is highly probable that this woman's principal deceleration in this moderate (18 mph Delta V) crash took place into the rear surface of the front seat. Given the rear compartment dimensions, she moved forward into the lap belt only a small amount before she contacted the seatback. Thus, the penetration of the lap belt into her abdominal area was not forceful enough to cause serious internal injury.

Seating location: Right rear
Sex: F
Age: 42
Height: 5 feet 2 inches
Weight: 170
Restraint used: Lap belt (ALR)
Proper use?. No

This passenger was wearing a lap belt similar to her seat mate's. There was no deformation of the compartment at this seating position.

Injuries	AIS	Probable Source
Abrasion, left forehead	1	Rear surface of front seat
Contusion, mid-abdominal area	1	Lap belt
Contusion, left knee	1	Rear surface of front seat
Contusion, right knee	1	Rear surface of front seat

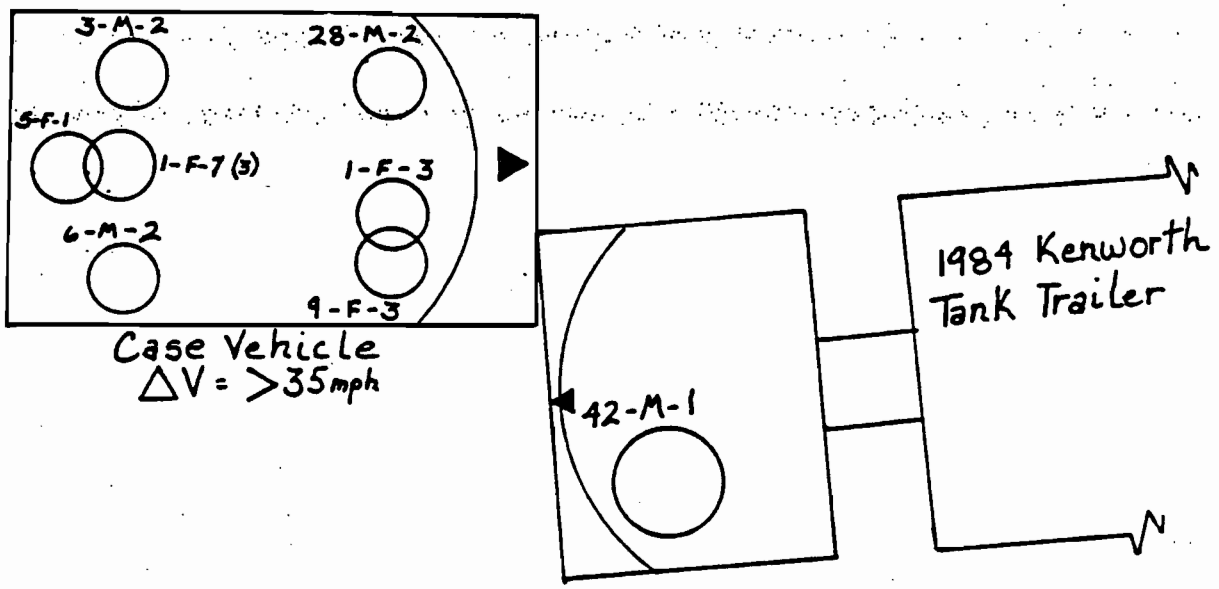
She was treated and released at an area hospital. A Safety Board followup interview one month after the accident revealed that she was experiencing abdominal soreness and bruising was still evident.

The precrash adjustment of this woman's lap belt was described as "snug," but with the webbing positioned above the navel. Despite the incorrect placement of this lap belt, and the overweight condition of this woman, the Delta V was sufficiently low in this case (combined with her principal deceleration into the right front seatback) to prevent serious internal injury.

The most serious injury sustained in this crash was the contused thigh of the Malibu driver. All others, restrained and unrestrained, suffered only minor injuries. If the rear seat passengers in the Malibu had been wearing lap/shoulder belts, they probably would not have sustained minor facial injuries.

CASE 22 (FTW-86-H-OR02)

Case vehicle:	1979 Chevrolet Impala station wagon
Case vehicle weight:	4,700 pounds
Case vehicle Delta V:	35 mph



Circumstances

A 1979 Chevrolet Impala station wagon struck a 1984 Kenworth tractor-trailer (gasoline tanker) head-on, right front to right front. The station wagon was driven by a 28-year-old man accompanied by six other passengers who ranged in age from 10 months to 9 years. None of the stationwagon occupants were restrained.

The truck was hauling 8,600 gallons of gasoline at a driver-estimated 55 mph when the impact occurred. The estimated right front to right front structural overlap in the collision was 24 inches; the crash destroyed the passenger car and resulted in a post-crash gasoline fire that substantially consumed the gasoline truck.

The station wagon driver received moderate injuries. The right front passengers, a 10-month-old infant girl and a 9-year-old girl, received moderate to serious injuries. Injuries sustained by the rear seat passengers varied, with a 10-month-old infant girl being held at center rear and a 6-year-old boy in the right rear receiving the most serious injuries. The 3-year-old boy at left rear received moderate injuries; the 5-year-old girl at center rear received only minor injuries.

Restraint and Injury

Seating location: Driver
Sex: M
Age: 28
Restraint used: None
Proper use? NA

This driver was not wearing the available 3-point lap/shoulder belt. There was forward displacement of the steering assembly and distortion of the upper instrument panel surface in front of the driver. Forward displacement of the lower instrument panel surface was also noted at both the left and right sides of the steering column.

Injuries	AIS	Probable Source
Closed head injury	2	Steering assembly and windshield
Unspecified neck injury	1	Steering assembly and windshield
Laceration, right knee and below	1	Lower instrument panel
Multiple contusions, abrasions	7	Frontal interior

The forces acting on the Chevrolet driver were not as great as those acting through the right side of the vehicle, due to the rapid counterclockwise rotation. It would be difficult to say that his injury level would have been reduced had he been restrained by the available system. With the speed involved, it is quite likely that some level of moderate injury would still have occurred.

Seating location: Right front, on lap of a 9-year-old girl
Sex: F
Age: 10 months
Restraint used: None
Proper use? NA

There was substantial rearward distortion of the front area at this position. The A pillar was displaced rearward several inches, and exterior components apparently intruded into the passenger compartment at windshield level. Accurate documentation of the compartment compression was not possible, due to extrication alterations. The seatback at this position was deformed forward several inches, due to loading by the rear seat occupants. The instrument panel forward of this seating position was found with substantial deformation, pushed inward and upward from its lower surface.

Injuries	AIS	Probable Source
Closed head injury w/neurologic defect	3	Instrument panel
Occipital hematoma	1	Instrument panel
Contusion, right check	1	Instrument panel
Laceration, left hand	1	Instrument panel

This child was most likely compressed between the instrument panel and the 9-year-old who was reportedly holding her at the time of the crash. If this infant had been properly restrained at center front in an adequate child safety seat, she probably would have escaped without serious injuries.

Seating location: Right front (holding infant)
Sex: F
Age: 9
Restraint used: None
Proper use? NA

This child was not wearing the available 3-point lap/shoulder belt. It was reported that she was holding a 10-month-old child on her lap at the time of the collision. See previous occupant discussion for description of compartment, postcrash.

Injuries	AIS	Probable Source
Pulmonary contusion	3	Instrument panel
Comminuted fracture, right ulna	3	instrument panel
Comminuted fracture, right radius	3	Instrument panel
Displaced fracture, left ulna	3	Instrument panel
Displaced fracture, left radius	3	Instrument panel

The 9-year-old probably would have received serious injuries even if she had been properly restrained by the 3-point lap/shoulder belt. This seating compartment had extensive intrusion from exterior components which penetrated at approximately the level where a restrained occupant's head and upper torso would have been positioned due to the shoulder strap. It could be speculated that this accident would not have been survivable for a fully restrained adult occupant because of that extensive intrusion.

Seating location: Left rear
Sex: M
Age: 3
Restraint used: None
Proper use? NA

This boy was not restrained by the available lap belt. There was no intrusion of the passenger compartment at this position. However, the back cushion of the front seat was deformed forward several inches directly in front of this occupant's precrash seating position.

Injuries	AIS	Probable Source
Fractured right metatarsals	2	Rear of front seat
Laceration, right forehead	1	Rear of front seat
Nonpenetrating laceration, left abdominal wall	1	Interior sidewall components
Unspecified closed head injury	2	B pillar and rear of front seat
Contusion, bridge of nose	1	B pillar and rear of front seat
Contusion, left cheek	1	B pillar
Abrasion, anterior right lower leg	1	Rear of front seat
Fracture, right hand metacarpal	2	Rear of front seat

This boy was admitted to a local hospital for 3 days due to the closed head injury and fractured right foot.

This little boy sustained less serious injuries than would normally be expected in an accident of this severity. He was allowed to decelerate into the rear surface of the front seatback without serious injury. He should have been in a child safety device appropriate for his size and weight. Given the severity of this collision, it is very likely that serious to critical injuries would have occurred if this boy had been lap belted.

Seating location: Center rear, on lap of 5-year-old girl
Sex: F
Age: 10 months
Restraint used: None
Proper use? NA

The back cushion of the front seat in front of this infant was deformed forward several inches. Multiple scuffs on the rear surface upholstery were noted across the entire width of the front seatback cushion.

Injuries	AIS	Probable Source
Intra-abdominal injury (required surgery)	7	Compression between 5-year-old holding her and front seatback
Fracture, right femur	3	Compression between 5-year-old and front seatback

This infant spent an unspecified period of time in an area hospital for surgery and other treatment.

If this infant had been properly restrained in a child safety seat, it is unlikely that any serious injuries would have occurred. However, there was insufficient space to install a safety seat for this child.

Seating location: Center rear (holding infant)
Sex: F
Age: 5
Restraint used: None
Proper use? NA

This child was not wearing the available static lap belt at her seating position. She was reportedly holding a 10-month-old child at the time of the accident. The back cushion of the front seat was deformed forward several inches in front of this seat position. Multiple scuffs on the rear surface upholstery were noted across the entire width of the front seatback cushion.

Injuries	AIS	Probable Source
Abrasion, right wrist	1	Rear of front seatback
Superficial abrasions, contusions	1	Rear of front seatback

She was checked at an area hospital and released without significant injury.

The 5-year-old's deceleration was cushioned by the infant she was holding at the time of the crash. Even without the cushioning, this child probably would not have sustained serious injury, due to the containment provided by the rear surface of the front seatback. If this passenger had been lap belted, her entire deceleration would have been into the 2-inch-wide restraint webbing, and serious internal injuries might well have resulted from such a deceleration.

Seating location: Right rear
Sex: M
Age: 6
Restraint used: None
Proper use? NA

This child was not wearing the available lap belt at his seating position. There was probably exterior metal intrusion into this compartment area. Also, the back cushion of the front seat was deformed forward several inches at the front of this seating position. Multiple areas of scuffs were noted across the rear surface of the front seatback forward of this seat position.

Injuries	AIS	Probable Source
Laceration (1 inch), over left eye	1	Intrusion of exterior metal
Laceration (2 inch), under lower lip	1	Intrusion of exterior metal
Avulsion, front tooth	1	Intrusion of exterior metal
Puncture, right shoulder crest	1	Intrusion of exterior metal
Laceration (3 inch), right side neck	2	Intrusion of exterior metal
Hematoma, right forehead	1	B pillar
Mild closed head injury	2	B pillar
Large laceration of tongue	2	Forces transmitted through teeth
Abrasion, right knee	1	Rear of front seat
Chemical keratitis, left eye	1	Battery acid or fuel spill

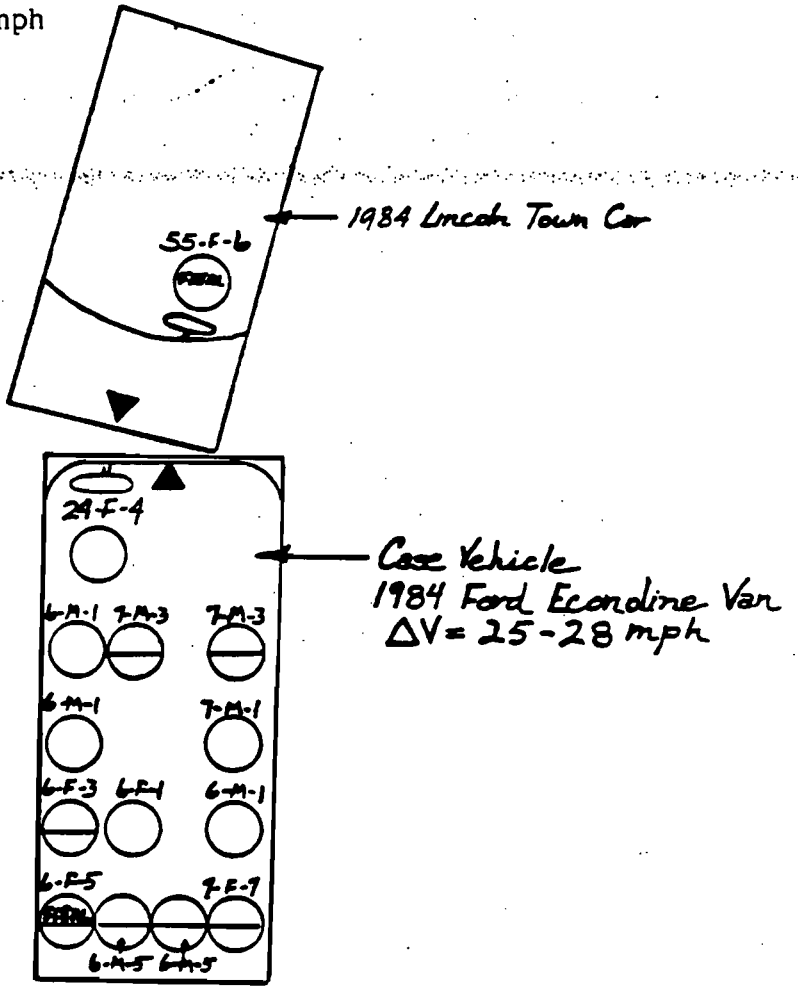
This boy required 3 days of hospitalization.

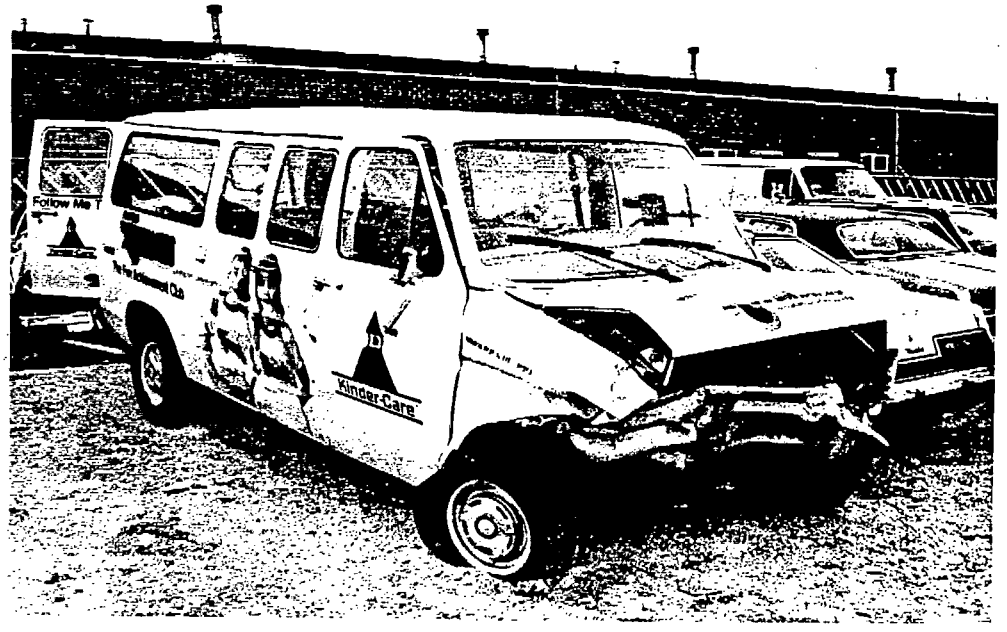
While use of a lap belt by this boy might have prevented the facial lacerations and contusions received from intruding exterior components, the lap belt itself would probably have resulted in a more serious level of injuries. A deceleration impulse of 35 mph into the 2-inch-wide lap belt could have caused serious intra-abdominal injuries, regardless of pre-crash adjustment. The probability of head or cervical injury would have been increased by jackknifing over the lap belt webbing.

If a lap/shoulder belt had been available to, and worn by, this boy, he could probably have ridden down the deceleration with only moderate contusions resulting from the restraint webbing. With upper torso restraint, his head would not have been allowed to contact the B pillar and intruding exterior metal.

CASE 23 (CHI-85-H-OR18)

Case vehicle: 1984 Ford Econoline Van
Case vehicle weight: 4,935 pounds
Case vehicle Delta V: 25-28 mph





Circumstances

A 1984 Ford Econoline van, configured for 19 passengers, struck a 1984 Lincoln Town Car. The collision destroyed the front structure of both vehicles, with rearward structural collapse 20 inches at the right front of the van and 28 inches at the left front of the Lincoln.

The impact resulted in fatal injuries to the unrestrained 55-year-old woman driving the Lincoln and serious injuries to the unrestrained 24-year-old woman van driver. One of the correctly lap belted van passengers, a 6-year-old girl seated at the extreme left rear position, sustained cervical fractures, head injuries, and massive internal injuries which proved fatal. Five of the remaining 6 correctly lap belted van passengers, all 6- or 7-year-olds, sustained serious to critical injuries which varied from pelvic fractures with abdominal injuries to head injuries. The 5 children who were not wearing lap belts received only minor injuries. This was not a severe impact for the van.

This case should be compared with No. 4 involving a van occupied by lap belted and unrestrained teenagers, with similar results.

To the extent that the lower framework of the bench seats in this van deformed forward, it probably greatly helped to reduce the injury of the children, due to energy dissipation over a much greater distance than would have been allowed with rigid, non-deforming framework.

It is possible that if the lap belt webbing anchors had been mounted on the seat framework, rather than on the floor, the belted children's injuries might have been less severe. By allowing the occupant to "ride down" the impulse as the seats deformed, without the floor-anchored webbing pulling the lower body downward, lower forces might have been transmitted to these children's bodies.

Restraint and Injury

Seating location: Driver
Sex: F
Age: 24
Height: 5 feet 5 inches
Weight: 125
Restraint used: None
Proper use? NA

The van driver was not wearing the 3-point lap/shoulder belt provided at her position. Witnesses said that, just before the van went out of control and crashed, the van driver apparently "passed out" and leaned over toward the right side of the van's front passenger compartment. This action would have placed her upper torso rearward of the van's engine cover which was located center front, between the driver's seat and right front passenger's seat. There was extensive forward displacement of the steering wheel rim, at the 12 to 5 o'clock area, along with substantial damage and distortion to the left rear surface of the engine cover. There were depressions in the instrument panel surface at the top center and at the lower left, between the steering column and left side door. The driver's seat was found at its forwardmost adjustment, and the seatback was displaced forward several inches at the top right.

Injuries	AIS	Probable Source
Multiple facial contusions	2	Instrument panel
Multiple small facial lacerations	1	Engine cover
Fractures, left side 1 and 2 ribs	1	Steering assembly
Contusion, left upper chest	2	Steering assembly
Bilateral pulmonary contusions	4	Engine cover and steering assembly
Avulsion fracture, right elbow	3	Engine cover
Contusion, right clavicular area	1	Engine cover
Large laceration, left thigh	2	Engine cover
Multiple contusions, left leg	1	Engine cover, instrument panel
Multiple contusions, right leg	1	Engine cover, instrument panel
Concussion with amnesia	3	Instrument panel
Abrasions, right hand	1	Frontal interior
Abrasions, left hand	1	Frontal interior

This woman required 14 days of hospitalization.

Her injury level would probably not have changed had she been wearing the available 3-point lap/shoulder belt. If she did indeed "pass out" and lean toward the right, the leaning action would have taken her from behind the shoulder strap. Even the amount of pre-impact inboard leaning shown by her contact points would have negated the value of the shoulder strap, leaving only a lap belt to decelerate into. Her head and upper torso would have contacted the steering assembly and instrument panel, while her lower abdomen would have been at the mercy of the lap belt. All things considered, this driver probably rode down the impact as well as could be hoped for in this accident.

Seating location: Bench 1, extreme left
Sex: M
Age: 6
Height: 47 inches
Weight: 48
Restraint used: None
Proper use? NA

There were several inches of forward displacement at the upper right side of the driver's seat back, directly forward of this seating position.

Injuries	AIS	Probable Source
Laceration, right side lower lip	1	Driver's seatback
Abrasion, right side forehead	1	Driver's seatback
Abrasion, right side face	1	Driver's seatback
Abrasion, inner right thigh	1	Driver's seatback

This child was admitted to a local hospital for an unspecified period.

Although this child said that he was wearing the static lap belt provided, the evidence is that he was unrestrained. This child's size would not have allowed him, if belted, to make the contacts which were apparent in the area of his position. Being unrestrained, he was in fact allowed to decelerate into the relatively forgiving rear surface of the driver's seat.

Seating location: Bench 1, inside left
Sex: M
Age: 7
Height: 42 inches
Weight: 61
Restraint used: Lap belt (static)
Proper use? Yes

This boy was wearing a static lap belt at the time of the collision. The system used incorporated a lift-release type of buckle, adjustable on a 37-inch length of webbing, and a latchplate sewn onto a 30-inch length of webbing. Both webbing components were floor anchored and entered the seating area by passing between the junction of the upper and lower cushions. The child related that his lap belt was "snug," positioned low across his hips.

Injuries	AIS	Probable Source
Bilateral pelvic fracture	2	Lap belt
Abrasion, left flank	1	Lap belt
Abrasion, right flank	1	Lap belt
Closed head injury with neurologic defect	3	Driver's seatbase
Contusion/abrasion, bridge of nose and above	2	Driver's seatbase

This child spent 7 days at an area hospital.

This child's injuries can be attributed directly to the lap belt he was wearing. It appears, considering the area and type of pelvic injuries, that the lap belt was worn in what is normally considered to be a proper manner. He sustained a bilateral pelvic fracture caused by decelerating into the belt webbing while his upper torso jackknifed over into a head contact with the rigid base of the driver's seat. Had a lap belt not been worn, this child's deceleration would have been into the rear cushion of the driver's seat, the driver's body, and the surface of the engine cover, and some level of moderate to serious injury could have occurred.

Seating location: Bench 1, extreme right
Sex: M
Age: 7
Height: 4 feet 6 inches
Weight: 60
Restraint used: Lap belt (static)
Proper use? Yes

This boy was wearing the lap belt at his seat. It was similar to the other lap belts in the van. The webbing was floor-anchored. There was substantial forward deformation of the right front seatback, directly in front of this boy's seat.

Injuries	AIS	Probable Source
Comminuted fracture, left iliac wing	3	Lap belt
Contusion, lower abdomen from right pelvic area to left pelvic area	1	Lap belt
Contusion, upper forehead	1	Right front seatback
Abrasion, lower left leg	1	Right front seatback
Abrasion, left calf	1	Right front seatback

This boy was in a hospital for 5 days.

Although the seatback of the bench occupied by this boy and the boy to his left was loaded by the two unrestrained outboard occupants of the second bench, it is not likely that this loading contributed to the injuries sustained by the two boys on the first bench. First, another boy on the first bench, unrestrained, was also subject to this loading but remained largely unhurt. More significantly, three of the four children lap belted on the last bench sustained critical and fatal injuries, yet their seatback was not loaded from behind at all.

This child's serious pelvic injury was the result of the lap belt being worn at the time of impact. Because his height was much greater then that of the child at left position on this bench, his head contact was directed into the upper area of the seatback in front of him (the right front seatback). This area of contact was much more forgiving than the area struck by the lap belted boy to his left. Consequently, this boy on the extreme right suffered no serious head injury. The seatback in front of him deformed forward, allowing a controlled or contained deceleration.

Seating location: Bench 2, extreme left
Sex: M
Age: 7
Height: 45 inches
Weight: 50
Restraint used: None
Proper use? NA

This child was not wearing the static lap belt available at his position. There was extensive forward displacement of the first bench seatback directly in front of this position, along with multiple scuffed areas. Also noted was forward deformation of the lower framework and seatback framework of this occupant's bench (second bench).

Injuries	AIS	Probable Source
Contusion, lower left leg	1	Bench rear framework

This child did not require medical attention. He was fully contained by the bench seat directly in front of him (Bench 1). His single injury, a contusion to his lower left leg, did not require medical attention.

Seating location: Bench 2, extreme right
Sex: M
Age: 7
Height: 47 inches
Weight: 52
Restraint used: None
Proper use? NA

This boy was not wearing the lap belt at his seating position. There was extensive forward deformation of the second bench's lower framework, along with the seatback, at this position. The seatback of the first bench was pushed forward several inches, with scuffed areas on the upholstered rear surface.

Injuries	AIS	Probable Source
Abrasion, lower left leg	1	Rear of bench 1
Contusion, left shoulder	1	Rear of bench 1
Contusion, right thigh	1	Rear of bench 1
Contusion, lower right leg	1	Rear of bench 1
Contusion, right knee	1	Rear of bench 1
Contusion, left knee	1	Rear of bench 1

This child was treated and released at a local hospital.

Seating location: Bench 3, extreme left
Sex: F
Age: 6
Height: 47 inches
Weight: 60
Restraint used: Lap belt (static)
Proper use? Yes

This child was wearing a static lap belt similar to those elsewhere in the van. The bench seat directly in front of this girl was extensively deformed: the lower framework was displaced forward several inches, and the back cushion was pushed forward into contact with the lower cushion. Also, scuffed areas were noted on the upholstered rear surface of the back cushion of the second bench.

Injuries	AIS	Probable Source
Head injury	3	Bench 2 rear framework
Fracture, left iliac crest	2	Lap belt
Contusion, bladder	3	Lap belt
Contusion, right hip	1	Lap belt
Contusion, left iliac crest	1	Lap belt
Abrasion/contusions, lower right leg	1	Bench 2 rear framework
Contusions, lower left leg	1	Bench 2 rear framework
Contusions, right hand	1	Rear surface of bench 2
Contusions, left hand	1	Rear surface of bench 2

This girl was hospitalized for 4 days. Her serious injuries can be attributed to the lap belt. The pelvic injuries strongly suggest proper belt placement.

Seating location: Bench 3, inside left
Sex: F
Age: 6
Height: 46 inches
Weight: 53
Restraint used: None
Proper use? NA

This girl was not wearing the static lap belt at her position. (For discussion of compartment, see bench 3, extreme left.)

Injuries	AIS	Probable Source
Contusion, forehead	1	Bench 2 seatback
Contusion, left thigh	1	Bench 2 lower frame
Contusion, right thigh	1	Bench 2 lower frame

This child was treated and released at an area hospital. This child's deceleration, and that of the small boy on the extreme right, were fully contained by the rear surface of the second bench seatback and only minor abrasions and contusions were sustained by them.

Seating location: Bench 3, extreme right
Sex: M
Age: 6
Height: 45 inches
Weight: 45
Restraint used: None
Proper use? NA

This child was not secured within the static lap belt available at his seating position. He said he had used the belt but that it came unlatched during the impact. The condition of the third bench compartment has been described.

Injuries	AIS	Probable Source
Abrasion, top of scalp	1	Rear of bench 2
Contusion, lower left leg	1	Rear of bench 2
Contusion, right knee	2	Rear of bench 2

This boy was treated and released at a local hospital. See comments on previous child's experience.

Seating location: Bench 4, extreme left
Sex: F
Age: 6
Height: 4 feet 1 inch
Weight: 55
Restraint used: Lap belt (static)
Proper use? Yes

This child was wearing a static lap belt with a lift release type of buckle, adjustable on a 37-inch length of webbing, and a latchplate sewn into a 30-inch length of webbing. Both webbing components entered the seating area from between the junction of the upper and lower seat cushions. The anchor points for both the latchplate and buckle webbing were located almost directly behind the longitudinal centerline of the seating position.

There was structural distortion of this seat's upper and lower framework, along with forward displacement of the back cushion of the third bench. Tubular framework components of both seats (benches 3 and 4) were bent forward several inches; however, the forward displacement of the fourth bench was limited by a spare tire carried unsecured beneath the seat. This spare tire and wheel moved forward during the collision--in effect, supporting the leading edge of the lower cushion and preventing further forward deformation of the framework. The postcrash location of the spare tire was directly beneath the inside left and extreme left positions. Also noted forward of the extreme left position was the inner fender over the left rear tire of the van.

Injuries	AIS	Probable Source
Subdural hematoma	4	Spare tire, inner fender, bench 2 lower frame
Subarachnoid hemorrhage	3	Spare tire, inner fender, bench 2 lower frame
Loss of consciousness	5	Spare tire, inner fender, bench 2 lower frame
Laceration, small bowel	5	Lap belt
Laceration, colon	5	Lap belt
Torn mesentery	4	Lap belt
Serosal tear	4	Lap belt
Retroperitoneum hematoma	3	Lap belt
Bilateral pulmonary contusions	3	Lower cushion frame, spare tire, inner fender
Cervical axial dislocation (quadriplegic)	5	Lower cushion frame, spare tire, inner fender
Small contusion, left cheek	1	Lower cushion frame, spare tire, inner fender
Contusion (6 inch x 6 inch) left hip	2	Lap belt
Contusion, left arm	1	Undetermined
Contusion, lower right leg	1	Bench 3 lower frame
Abrasion, lower right leg	1	Bench 3 lower frame
Contusions, lower pelvis	1	Lap belt

This child never regained consciousness. She was treated, with the aid of life-support equipment, for 3 days before being pronounced dead.

The injuries sustained as a result of lap belt usage by this child proved fatal. The injury severity was increased by the presence of an unsecured spare tire and wheel, which moved forward at impact to a position beneath and forward of this occupant. The jackknifing action over the lap belt accelerated the child's head into violent contact with the tire and wheel, resulting in brain and spinal injury. The lap belt itself penetrated her abdomen, resulting in massive internal trauma. The movement of the spare tire blocked the downward collapse of the lower seat cushion, presenting a rigid surface which resulted in compression of the child's chest and pulmonary contusions.

The location and type of abrasions and contusions to this child's pelvic area seem to indicate that the lap belt was positioned in an area generally considered to be proper. The type and location of her internal injury reinforce that indication. Insufficient evidence prevents an adequate assessment of belt tension.

Seating location: Bench 4, inside left
Sex: M
Age: 6
Height: 4 feet 2 inches
Weight: 50
Restraint used: Lap belt (static)
Proper use? Yes

This child was restrained by a static lap belt similar to others in the van. For compartment description, see previous occupant.

Injuries	AIS	Probable Source
Contusion w/hematoma, forehead	1	Bench 3, spare tire
Subarachnoid hemorrhage	3	Bench 3, spare tire
Severe brain stem injury	5	Bench 3, spare tire
Bilateral fractures of iliac crests	2	Lap belt
Contusion, left lower abdomen	1	Lap belt
Contusion, right lower abdomen	1	Lap belt
Contusion, right ankle	1	Bench 3
Abrasion, right tibia area	1	Bench 3
Abrasion, left tibia area	1	Bench 3

This boy received initial care for 2 days at an area hospital before being transferred for long term care.

His injuries can also be attributed directly to the lap belt worn at the time of impact. Without the lap belt, there would have been no downward acceleration of his head into the spare tire and wheel or the lower framework of the third bench seat.

The nature of the child's pelvic injuries seems to indicate proper belt placement. Evaluation of belt tension was not possible, due to lack of evidence.

Seating location: Bench 4, inside right
Sex: M
Age: 6
Height: 4 feet 8 inches
Weight: 54
Restraint used: Lap belt (static)
Proper use? Yes

This child was restrained by a static lap belt similar to others in the van. For compartment description, see previous occupant.

Injuries	AIS	Probable Source
Subarachnoid hemorrhage, posterior fossa	3	Rear of bench 3
Subarachnoid hemorrhage, cranial/ cervical junction	3	Rear of bench 3
Spinal cord contusion (quadriplegic)	5	Rear of bench 3
Perforation of small bowel	5	Lap belt
Contusion w/hematoma, cecum	3	Lap belt
Abrasion/contusion, lower abdomen	3	Lap belt
Contusion w/hematoma, forehead	2	Rear of bench 3

This boy spent an extended period at a local hospital and then he was transferred to an extended care facility.

The location of the boy's intra-abdominal injuries are approximately in line with the top of the iliac crests, as could be expected due to loading if the belt rode up over the crests. If the belt had been improperly positioned prior to the force loading, the intra-abdominal injuries would have been to organs located higher up in the abdominal cavity. Thus, it appears the boy was wearing the lap belt correctly and that his serious to critical injuries were induced by it.

This child's height allowed his head, during a violent jackknifing induced by the lap belt, to make violent contact with the lower framework of the third bench seat and resulted in serious head injury along with spinal cord damage that rendered him quadriplegic.

Seating location: Bench 4, extreme right
Sex: F
Age: 6
Height: 4 feet 2 inches
Weight: 50
Restraint used: Lap belt (static)
Proper use? Yes

This child was wearing a static lap belt similar to others in the van. There were several inches of forward deformation at the right side lower framework of the fourth bench. The tubular frame members were bent forward to a point of contact between the bench's leading edge frame and the inner fender of the right rear tire. The back cushion of this bench was displaced forward by several inches at its top.

Injuries	AIS	Probable Source
Abrasion, right side forehead	1	Right side inner fender
Abrasion, right side face	1	Right side inner fender
Full depth laceration of tongue	2	Right side inner fender
Contusion, right side pelvis	1	Lap belt
Contusion, left side pelvis	1	Lap belt
Unspecified leg injury	7	Undetermined

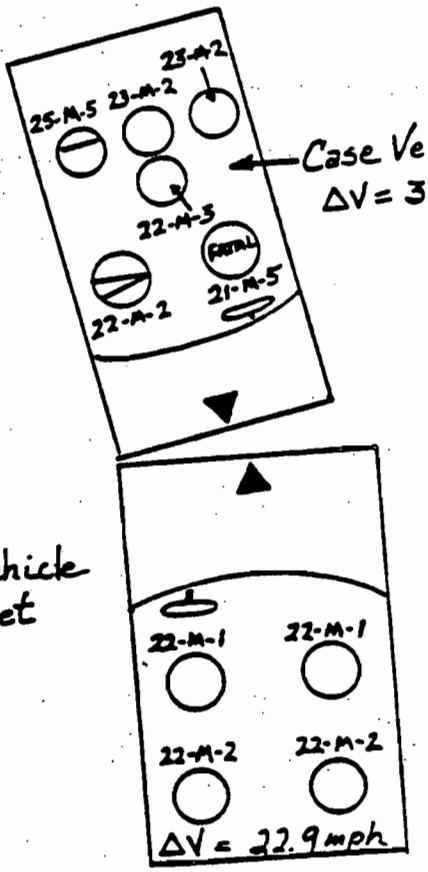
This girl was hospitalized for 2 or 3 days.

She was afforded some degree of deceleration by the interior sidewall of the van and did not sustain serious to critical injuries comparable to the other lap belted children in the van. Had she been unbelted, she probably would have sustained a moderate to serious level of injury, since the van's seating configuration did not provide containment for the position.

The Safety Board concludes that if the unbelted children in this case had been wearing the available lap belts, they probably would have sustained injuries similar to those sustained by the lap belted children. Considering the injuries sustained by the lap belted children (head, spine, and intra-abdominal), the Board concludes they would have fared much better if they had been restrained by lap/shoulder belts.

CASE 24 (ATL-85-H-OR21)

Case vehicle:	1979 VW Rabbit, 4-door
Case vehicle weight:	2,900 pounds
Case vehicle Delta V:	35.5 mph
Comparison vehicle:	1977 Chevrolet Impala
Comparison vehicle weight:	4,500 pounds
Comparison vehicle Delta V:	22.9 mph



This boy spent an extended period at a local hospital and then he was transferred to an extended care facility.

The location of the boy's intra-abdominal injuries are approximately in line with the top of the iliac crests, as could be expected due to loading if the belt rode up over the crests. If the belt had been improperly positioned prior to the force loading, the intra-abdominal injuries would have been to organs located higher up in the abdominal cavity. Thus, it appears the boy was wearing the lap belt correctly and that his serious to critical injuries were induced by it.

This child's height allowed his head, during a violent jackknifing induced by the lap belt, to make violent contact with the lower framework of the third bench seat and resulted in serious head injury along with spinal cord damage that rendered him quadriplegic.

Seating location: Bench 4, extreme right
Sex: F
Age: 6
Height: 4 feet 2 inches
Weight: 50
Restraint used: Lap belt (static)
Proper use? Yes

This child was wearing a static lap belt similar to others in the van. There were several inches of forward deformation at the right side lower framework of the fourth bench. The tubular frame members were bent forward to a point of contact between the bench's leading edge frame and the inner fender of the right rear tire. The back cushion of this bench was displaced forward by several inches at its top.

Injuries	AIS	Probable Source
Abrasion, right side forehead	1	Right side inner fender
Abrasion, right side face	1	Right side inner fender
Full depth laceration of tongue	2	Right side inner fender
Contusion, right side pelvis	1	Lap belt
Contusion, left side pelvis	1	Lap belt
Unspecified leg injury	7	Undetermined

This girl was hospitalized for 2 or 3 days.

She was afforded some degree of deceleration by the interior sidewall of the van and did not sustain serious to critical injuries comparable to the other lap belted children in the van. Had she been unbelted, she probably would have sustained a moderate to serious level of injury, since the van's seating configuration did not provide containment for the position.

The Safety Board concludes that if the unbelted children in this case had been wearing the available lap belts, they probably would have sustained injuries similar to those sustained by the lap belted children. Considering the injuries sustained by the lap belted children (head, spine, and intra-abdominal), the Board concludes they would have fared much better if they had been restrained by lap/shoulder belts.

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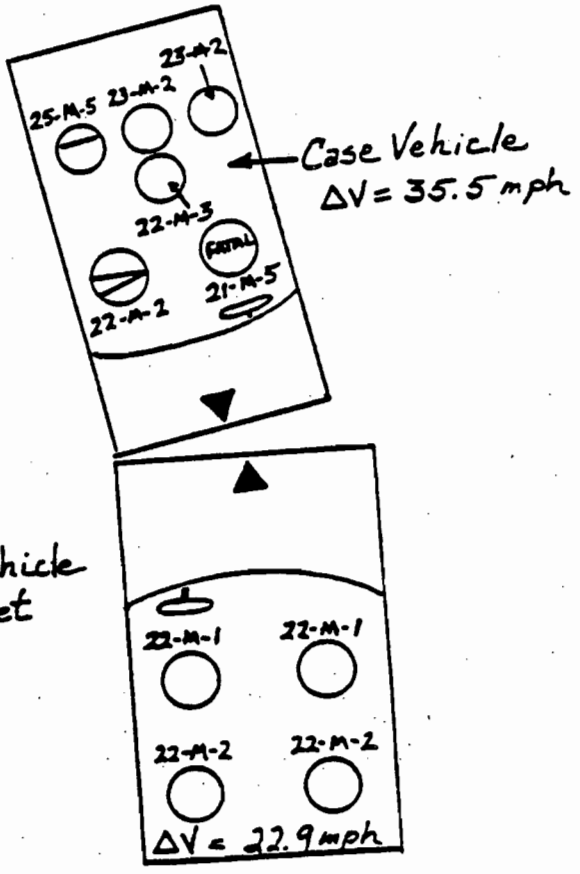


Circumstances

A 1979 VW Rabbit struck a 1977 Chevrolet Impala head-on. The Delta V for the VW was 35.5 mph, and for the Impala, about 23 mph. Both vehicles were substantially damaged, with rearward structural collapse reaching depths of 26 inches on the VW and 34 inches on the Chevrolet.

The small 5-passenger Rabbit was occupied by six men, with restraints in use by the right front and right rear passenger. None of the four 22-year-old men in the Chevrolet were restrained.

The unrestrained driver of the VW sustained fatal injuries. His lap/shoulder belted right front passenger escaped with only minor 1/ injuries. The lap belted right rear passenger received critical internal injuries, including ruptures of the aorta and colon, along with a fracture of his 3rd lumbar vertebra. The aorta damage required a 3-inch graft repair and the colon injury necessitated removal of more than 1 1/2 feet of damaged intestine. Injuries to the remaining three occupants of the VW's rear seat, all unbelted, were minor to moderate.

The four unrestrained male occupants of the Chevrolet sustained minor to moderate injuries. All were treated and released from a local hospital without further treatment.

Restraint and Injury

Seating location: Driver (VW)
Sex: M
Age: 21
Height: 5 feet 10 inches
Weight: 170
Restraint used: None
Proper use? NA

This driver was not wearing the available 3-point lap/shoulder belt. There was substantial rearward deformation of the instrument panel and steering assembly forward of the driver's seat. While the entire frontal area was compressed rearward, the steering wheel and column were pushed upward, with the lower rim circumference displaced forward by several inches. The driver's seatback showed massive structural distortion, primarily confined to the left side of the framework.

Injuries	AIS	Probable Source
Multiple head injury	5	Head liner above windshield
Open fracture, right femur	3	Compressed frontal interior
Fractured pelvis	2	Compressed frontal interior
Cervical injury (unspecified)	7	Force through head impact
Chest injury (unspecified)	7	Steering assembly

1/ This man had one AIS 2 (moderate) injury--a chest contusion from the shoulder belt. However, it is classified as AIS 2, rather than AIS 1 (minor) only because of its size (greater than 50-square cm). All his other injuries were minor.

This man was found without vital signs at the accident scene. He probably would have survived if he had been properly restrained by the available lap/shoulder belt. There was sufficient survivable space at his position to make this possible. Although some level of moderate to serious injuries would have been expected, partially due to seatback loading, they probably would have been similar to those of his restrained right front passenger.

Seating location: Right front (VW)
Sex: M
Age: 22
Height: 5 feet 7 inches
Weight: 160
Restraint used: Lap/shoulder belt (ELR)
Proper use? Yes

This occupant was wearing a 3-point, continuous loop, lap/shoulder belt with an ELR sensitive to webbing motion, a free-sliding latchplate, and a push-to-release type of buckle mounted to a rigid stalk. There was extensive rearward displacement of the frontal interior at this seat position. The extreme right side instrument panel, along with the right side A pillar, was compressed rearward several inches due to the impact force. There was also substantial distortion of this seat's lower and back framework, with forward displacement of the upper left side of the back cushion, due to loading by the rear seat passengers.

Injuries	AIS	Probable Source
Abrasion/contusion, extending from right neck to left chest	2 (size)	Shoulder belt
Laceration, left elbow	1	Instrument panel
Laceration, left wrist	1	Instrument panel
Laceration, left hand	1	Instrument panel
Contusion, abdominal area	1	Lap belt
Contusion, right knee	1	Lower instrument panel
Contusion, left knee	1	Lower instrument panel
Sprain, right foot	1	Below instrument panel

This fully restrained passenger rode down the impact forces with a much lower level of injuries than could be expected in a collision of this severity. His major injury was an AIS 2 contusion which resulted from the restraint shoulder strap. Had he been unrestrained, the expected injury from violent impacts with the A pillar and other frontal interior components could have been fatal. The restraint system's performance at the right front position was excellent.

Seating location: Left rear (VW)
Sex: M
Age: 23
Height: 6 feet
Weight: 175
Restraint used: None
Proper use? NA

This man was not wearing the available lap belt. There was extensive compartmental distortion which included several inches of forward displacement of the driver's seat framework. Both the upper and lower bench cushions of the rear seat were substantially deformed, at least partially due to impact from cargo stored behind the rear seat.

Injuries	AIS	Probable Source
Fractured right foot	2	Driver's seat framework
Laceration (3 inch), right knee	1	Driver's seat framework
Laceration, right foot	1	Driver's seat framework
Contusion, right foot	1	Driver's seat framework
Multiple unspecified abrasions	1	Driver's seat framework
Contusion, lip	1	Driver's seat framework
Contusion, left foot	1	Driver's seat framework

This passenger was treated and released at a local hospital emergency room. His forward reactive travel was contained by the rear surface of the driver's bucket seat. While it cannot be determined how much this contact contributed to the driver's injuries, it can be stated that it prevented serious injury to the subject passenger.

Had this passenger been restrained by the lap belt, his injury level could have reached comparable severity to that of the lap belted right rear passenger and to that of other young men lap belted in a Delta V 35-40 mph crash (Case 4).

Seating location: Center rear, on lap (VW)
Sex: M
Age: 22
Height: 5 feet 8 inches
Weight: 160
Restraint used: None
Proper use? NA

This man was seated on the lap of another man at the center rear and, consequently, had no restraint available. Inspection of this compartment area revealed extensive distortion to both the rear seat cushions and the framework of the front seats. The back cushion of the rear seat was deformed forward several inches, due to displaced cargo positioned behind it prior to the crash, and the inboard side of the left front seatback was pushed forward.

Injuries	AIS	Probable Source
Abrasion, forehead	1	Left front seat framework
Closed head injury with defect	3	Left front seat framework
Laceration, right hand	1	Left front seat framework
Unspecified intra-abdominal injury	7	Left front seat framework

This man required more than 2 weeks of hospitalization and lost more than 5 weeks of work. His injuries were undoubtedly made worse by loading from the man whose lap he was sitting on. Furthermore, his forward reactive travel could be only partially contained by the front bucket seats, due to the open space between the seatbacks. Consequently, his head was free to move between the seatbacks to a point of violent deceleration.

Seating location: Center rear (VW)
Sex: M
Age: 23
Height: 5 feet 10 inches
Weight: 175
Restraint used: None
Proper use? NA

This passenger was riding unrestrained with an adult male sitting on his lap. Substantial compartmental distortion was noted at this seat position, with both the back cushion of the rear seat and back framework at the front seats deformed forward several inches.

Injuries	AIS	Probable Source
Displaced fracture, left mandible	2	Front seat framework or man on lap
Large contusion, left face	2	Front seat framework or man on lap
Contusion, left forehead	1	Front seat framework or man on lap
Abrasion, left cheek	1	Front seat framework or man on lap
Contusion, nose	1	Front seat framework or man on lap
Contusion, left ribs	1	Front seat framework or man on lap
Contusion, left knee	1	Front seat framework or man on lap
Contusion, right knee		Front seat framework or man on lap

This man spent an unspecified period in the hospital. He lost approximately 30 days of work. His forward reactive travel was contained and cushioned by the occupant seated on his lap; therefore, use of the available static lap belt would probably not have increased nor reduced his minor to moderate injuries.

Seating location: Right rear (VW)
Sex: M
Age: 25
Height: 5 feet 8 inches
Weight: 185
Restraint used: Lap belt (ALR)
Proper use? Yes

This man was restrained by a lap belt that incorporated an ALR, a sewn-in latchplate attached to the retractable webbing, and a pushbutton release type of buckle. The buckle webbing entered the seating area by passing between the junction of the upper and lower seat cushions, at a point 17 inches inboard from the right interior sidewall, while the latchplate webbing entered from between the right interior sidewall and the lower bench. The buckle webbing was 13 inches long, and the latchplate webbing was 30 inches long. There was extensive deformation of the bench seat framework at this position. The rearmost framework of the lower cushion was distorted forward and up, resulting in the seat cushion angling downward at the front edge. The framework of the right front bucket seat was also extensively deformed directly forward of this seating area. Lower framework components of that seat were displaced forward and up, while the back cushion was pushed forward several inches.

Injuries	AIS	Probable Source
Small contusion, left side head	1	Right front seatback
Ruptured aorta (common iliac, 3-inch graft required)	5	Lap belt
Ruptured colon (18 inches removed)	5	Lap belt
Fracture, 3rd lumbar vertebra	3	Lap belt
Laceration, from behind left kidney around to left side of abdomen	2	Lap belt
Contusion across abdomen	2	Lap belt
Head injury, with amnesia, 6-7 days unconscious	5	Impact force

This man spent an extended period in area hospitals; as of 5 1/2 months after the crash, he had not returned to service with the armed forces.

His critical internal injuries can be attributed directly to the lap belt. While medical records were not obtained for detailed injury location description, the verbal descriptions given by the victim and family members seem to indicate that the lap belt penetrated his abdominal cavity above that area which is generally considered as proper lap belt placement. This location of penetration does not necessarily mean that the lap belt's preimpact placement was improper. His lower pelvic area was forced forward, due to rear compartment cargo deforming the bench seat lower framework at the cushion junction. The forward edge of the lower cushion was also deformed downward. The combined effects of the seat framework distortion would contribute to some degree of submarining by the occupant. This analysis is reinforced by consideration of his injuries, which appear to start low at the frontal abdominal area and rise to the level of the 3rd lumbar vertebra at the rear.

It is not known whether his loss of consciousness was due to a forceful head impact or was the result of hypoxia.

Had this passenger not been restrained by the lap belt, but by a properly fitted lap/shoulder belt, the life-threatening internal injuries would not have occurred.

Seating location: Driver (Chevrolet)
Sex: M
Age: 22
Height: 6 feet
Weight: 170
Restraint used: None
Proper use? NA

This driver was not wearing the available lap/shoulder belt at his position. There was no compartment compression at this position, but extensive forward deformation occurred to the instrument panel and steering assembly. The steering wheel rim and hub were displaced forward and toward the left interior, in line with the impact force. The plastic and vinyl instrument panel components were broken and deformed.

Injuries	AIS	Probable Source
Abrasion, left eyebrow area	1	Windshield
Small laceration, left eyebrow area	1	Windshield
Abrasion, left elbow	1	Instrument panel
Abrasion, left knee	1	Instrument panel
Abrasion, right knee	1	Instrument panel
Sprained right wrist	1	Instrument panel
Numerous contusions, chest area	1	Steering assembly
Small laceration, right neck	1	Broken panel component
Contusion, center forehead	1	Windshield

He was treated and released at a local hospital emergency room. There was no work loss as a result of his injuries.

(See comments at the end of this case summary.)

Seating location: Right front (Chevrolet)
Sex: M
Age: 22
Height: 6 feet 5 inches
Weight: 175
Restraint used: None
Proper use? NA

This man was not wearing the 3-point lap/shoulder belt provided at his position. There was extensive forward deformation of the instrument panel forward of and inboard from this seat position. An area of windshield damage, broken with a "spiderweb" effect, was found slightly inboard and forward of the approximate centerline of this position.

Injuries	AIS	Probable Source
Multiple abrasions/lacerations, face	1	Windshield
Sprained right shoulder	1	Instrument panel
Abrasions, left arm	1	Instrument panel
Small laceration, left hand	1	Instrument panel
Abrasion, right wrist	1	Instrument panel
Small lacerations, left knee	1	Instrument panel
Abrasion, left knee	1	Instrument panel
Small laceration, right knee	1	Instrument panel

He was treated and released at a local hospital and returned to work immediately.

(See comments at the end of this case summary.)

Seating location: Left rear (Chevrolet)
Sex: M
Age: 22
Height: 6 feet
Weight: 180
Restraint used: None
Proper use? NA

This man was not wearing the lap belt provided at his position. The front bench seatback was across its entire width. In addition, scuffs were noted on the vinyl material covering the B pillar forward and left of this position.

Injuries	AIS	Probable Source
Small laceration, right eyebrow	1	Rear of front seat
Abrasions to forehead	1	B pillar
Unspecified head injury	2	B pillar
Laceration, left elbow	1	Interior sidewall
Fracture, left radius	2	Interior sidewall and B pillar
Fracture, left ulnar	2	Interior sidewall and B pillar
Small laceration on scalp	1	Interior sidewall and B pillar
Four fractured teeth	1	Interior sidewall and B pillar

He was treated and released at an area hospital and stayed home from work for 1 day.

(See comments at the end of this case summary.)

Seating location: Right rear (Chevrolet)
Sex: M
Age: 22
Height: 6 feet 5 inches
Weight: 190
Restraint used: None
Proper use? NA

This man was not wearing the lap belt provided at his seat position. There was extensive forward deformation of the front seatback framework across its entire width. Numerous scuffs were also noted on the vinyl upholstery covering the rear of the front seatback.

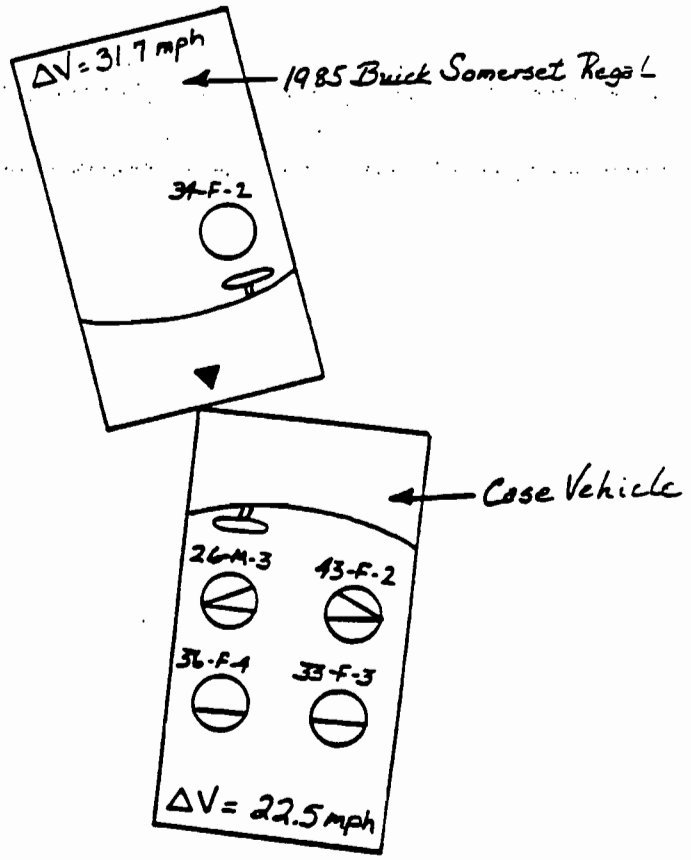
Injuries	AIS	Probable Source
Abrasion, mid-forehead	1	Rear of front seat
Contusion, left wrist	2	Rear of front seat
Comminuted fracture, left radius	2	Rear of front seat
Fracture, left ulnar styloid process	2	Rear of front seat
Laceration, right hand	1	Interior objects
Contusions, left arm	1	Rear of front seat
Contusion, left knee	1	Rear of front seat
Laceration, left foot	1	Front seat lower framework
Laceration, left cheek	1	Front seat framework

He was treated and released at a local hospital and was able to return to work.

The unrestrained occupants of the Chevrolet did not suffer any life-threatening injuries. All were treated and released at a local hospital; the major injuries were AIS 2 fractures to the rear seated passengers. Forward reactive travel was contained well by the vehicle interior. It would be difficult to say that the front seat occupants could have come out any better if they had been restrained by the available lap/shoulder belts. Given the experience of other rear seat occupants in this study, the Safety Board thinks that the rear seated passengers could have sustained serious restraint-related injuries had they been wearing the available lap belts. This is a more difficult assessment in this case than in some others, since the Delta V of approximately 23 mph places the expected crash force injury in an area of ambiguity. Especially for large cars, the crash injury level for 20 to 25 mph collisions is more unpredictable. However, in this case it can be stated with certainty that the rear seat occupants rode down the crash forces very well by containment only.

CASE 25 (MKC-86-H-OR01)

Case vehicle: 1981 Ford Fairmont station wagon
Case vehicle weight: 3,583 pounds
Case vehicle Delta V: 22.5 mph



Circumstances

A 1981 Ford Fairmont station wagon was struck on the left front corner by the center front of a 1985 Buick Somerset Regal. Both vehicles received substantial front structural damage, with rearward collapse reaching over 30 inches at the Ford's left front and over 23 inches at the left side front of the Buick.

The Ford station wagon was being driven by a 26-year-old man who was wearing the lap/shoulder belt provided at his position. Occupants of the Ford included a 40-year-old female right front passenger, also fully restrained by a lap/shoulder belt, along with a 36-year-old female left rear and 33-year-old female right rear passengers. Both rear seat passengers were wearing the available lap belt restraints. The 34-year-old woman driving the Buick was unrestrained.

The collision resulted in moderate injuries to the Ford's driver and right front passenger. The lap belted left rear Ford occupant sustained serious injuries, including a severely avulsed small bowel mesentery which required a resection of more than 30 inches, due to multiple areas of torn mesentery. The right rear occupant suffered multiple fractures of the lumbar vertebrae. Injuries sustained by the Buick driver were moderate.

Restraint and Injury

Seating location: Driver
Sex: M
Age: 26
Height: 5 feet 10 inches
Weight: 205
Restraint used: Lap/shoulder belt (ELR)
Proper use? Yes

This man was wearing the 3-point, continuous loop, lap/shoulder belt with an ELR, a free-sliding latchplate, and a pushbutton release type of buckle attached to a flexible stalk. The ELR was sensitive to vehicle motion and did not have a tension relief mechanism. The steering assembly was deformed outboard due to front structural collapse, and the lower instrument panel was distorted.

Injuries	AIS	Probable Source
Laceration (4 cm), right knee	1	Lower instrument panel
Fracture, right tibial plateau	2	Lower instrument panel
Comminuted fracture, right radius	3	Steering assembly
Contusion, central chest area	1	Shoulder strap
Contusion, lower left leg	1	Lower instrument panel

This man spent 3 1/2 days in an area hospital and lost 6 1/2 days of work.

(See comments at the end of this case summary.)

Seating location: Right front
Sex: F
Age: 40
Height: 5 feet 6 inches
Weight: 170
Restraint used: Lap/shoulder belt
Proper use? Yes

This woman was wearing a lap/shoulder belt similar to the driver's. The lower instrument panel was distorted forward of her seat position.

Injuries	AIS	Probable Source
Contusion, left lower chest	1	Shoulder strap
Contusion, across entire abdomen	2	Lap belt
Abrasion, left flank	1	Lap belt buckle
Contusion, left mid forearm	1	Steering wheel
Contusions and abrasions, right knee	1	Lower instrument panel
Contusions and abrasions, left knee	1	Lower instrument panel
Contusion, right side neck	1	Shoulder strap

This woman was treated at the emergency room of a local hospital for several hours before being released. She was unable to work for 9 days.

Seating location: Left rear
Sex: F
Age: 36
Height: 5 feet
Weight: 160
Restraint used: Lap belt (ALR)
Proper use? Yes

This woman was wearing a lap belt with an ALR, a sewn-in latchplate attached to a 35-inch length of retractable webbing, and a pushbutton release type of buckle attached to a length of webbing extending 8 inches through the junction of the bench seat cushions. There was no deformation of the passenger compartment at this position. The plastic covering of the lap belt retractor was broken, due to force loading. This woman said her belt was about her abdomen with a "snug" tension.

Injuries	AIS	Probable Source
Contusion, left triceps	1	Left sidewall
Abrasion, distal right tibia	1	Rear surface driver's seat
Abrasion/contusion, lower abdomen	2	Lap belt
Avulsion injury, abdominal wall	2	Lap belt
Avulsion injury, abdominal fascia	2	Lap belt
Avulsion injury, small bowel mesentery	4	Lap belt
Abrasion, left iliac crest	1	Lap belt
Abrasion, right iliac crest	1	Lap belt
Large bruise, lower right leg	2	Driver's seat lower frame
Laceration, lower right leg	1	Driver's seat lower frame
Contusion, posterior right thigh	1	Rear seat frame
Contusion, posterior left thigh	1	Rear seat frame

This woman spent 11 days in an area hospital and lost an unspecified number of days' work.

(See discussion at the end of this case summary.)

Seating location: Right rear
Sex: F
Age: 33
Height: 5 feet 4 inches
Weight: 118
Restraint used: Lap belt (ALR)
Proper use? Yes

This woman was wearing a lap belt similar to the left rear passenger's. There was no permanent compartment deformation at this seat position. Again, the plastic retractor covering was broken, due to force loading. This woman said she had her lap belt low across her hips and snug.

Injuries	AIS	Probable Source
Fracture, second and third lumbar vertebrae	3	Force through lap belt
Contusion, lower abdomen	1	Lap belt
Contusion, upper left arm	1	Contact with lower extremities
Contusions, lower right leg	1	Rear of front seatback
Contusion, lower back	1	Impact forces

This woman spent 10 days in a hospital before release in a body cast. At the time of the Safety Board investigation (late 1985), she expected the body cast to be necessary for 2 to 6 months.

This crash cannot be considered a severe collision for the Ford occupants. A much higher level of injuries was sustained by each of them than would be expected with a Delta V of approximately 22.5 mph.

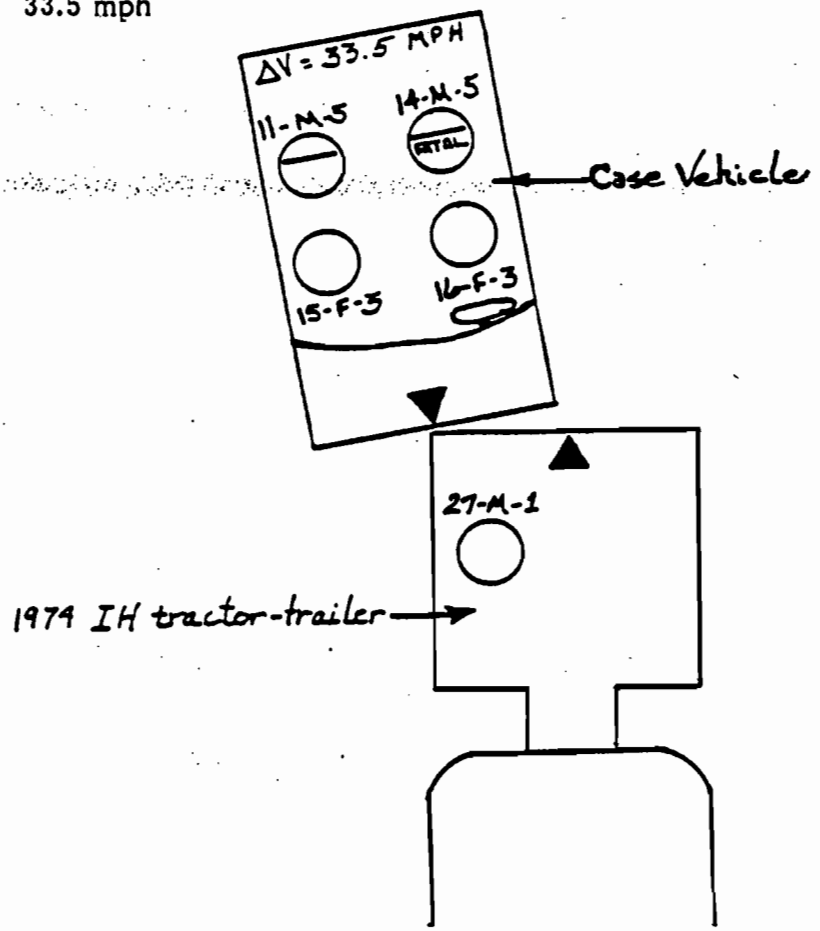
There were no indications of improper belt use. The nature of the Ford's belt systems, both front and rear, should provide a snug tension, with automatic tensioning of the front belts and ALRs on the rear lap belts. The most seriously injured of the Ford's occupants, the woman wearing a lap belt in the left rear, had abrasions on both the right and left iliac crests, indicating a lap belt positioning in the area generally considered to be proper. Yet she sustained an intra-abdominal injury severe enough to require removal of more than 30 inches of small intestine. In addition, a large area of her abdominal subcutaneous tissue was avulsed by the lap belt's penetration.

The other lap belted woman in the rear said she had the belt positioned low and snug. Medical record description of her abdominal contusions and abrasions were not sufficient to make an independent evaluation of proper or improper fit. She received multiple fractures of the mid-lumbar vertebrae, necessitating 10 days hospitalization and the fitting of a body cast for an extended period.

All the documented serious injuries sustained by the rear seated Ford passengers can be attributed directly to the lap belts in use. All but one of the documented injuries not attributed to the lap belts were minor. The non-use of lap belts by these two women might have resulted in a few additional contusions, as the impact forces were contained by the rear surface of the front bench seat. The serious internal and spinal injuries would not have occurred, however. Properly fitted lap/shoulder belts also would have prevented these injuries.

CASE 26 (NYC-85-H-OR16)

Case vehicle: 1985 Ford Escort, 2-door
Case vehicle weight: 2,824 pounds
Case vehicle Delta V: 33.5 mph



Circumstances

A 1985 Ford Escort struck, center front to left front corner, a 1974 International Harvester semi-truck and trailer. The collision forces completely destroyed the front structure of the Escort, with rearward structural collapse reaching 29 inches at the left front.

The Ford Escort was driven by an unrestrained 16-year-old girl. An unrestrained 15-year-old girl was the right front passenger, a 14-year-old boy was lap belted left rear, and an 11-year-old boy was lap belted in the right rear position. The driver sustained minor abrasions, lacerations, and contusions, deep lacerations of the lower extremities, and an open fracture of the left femur. The right front occupant sustained similar injuries. Both lap belted rear seat passengers sustained massive internal injuries, including torn and avulsed mesentery, avulsed and ruptured intestines, and substantial blood loss. In addition, the 11-year-old boy in the right rear received a lap belt induced fracture of the spinal column, which rendered him paraplegic. The 14-year-old boy in the left rear seat died as a result of his lap belt induced internal injuries before medical treatment could provide repair.

Restraint and Injury

Seating location: Driver
Sex: F
Age: 16
Height: unknown
Weight: 180
Restraint used: None
Proper use? NA

This driver was not using the available lap/shoulder restraint provided at her seat position. There was substantial compartmental compression at this position. Extensive distortion was found, with forward displacement of the steering assembly and rearward displacement of the instrument panel, A pillar, and lower floor components.

Injuries	AIS	Probable Source
Superficial abrasion, left forehead	1	A pillar
Small laceration, bridge of nose	1	A pillar
Unspecified contusion, chest	1	Steering assembly
Unspecified abrasion, chest	1	Steering assembly
Contusion/abrasion, abdomen	1	Steering assembly
Unspecified contusion/abrasion, both hands	1	Instrument panel
Avulsion, right leg below knee	2	Instrument panel
Open fracture, left femur	3	Instrument panel

She was admitted to a local hospital for an unspecified period. Although the fractured femur is classified as a serious injury (AIS 3), it was not life-threatening.

Seating location: Right front
Sex: F
Age: 15
Height: 5 feet 3 inches
Weight: 150
Restraint used: None
Proper use? NA

This girl was not wearing the available lap/shoulder restraint provided at her seat position. An inspection of the Escort's right frontal interior revealed extensive distortion of the instrument panel.

Injuries	AIS	Probable Source
Small lacerations, forehead	1	Windshield
Abrasion, left chest wall	1	Instrument panel
Laceration, left elbow	1	Instrument panel
Laceration, right elbow	1	Instrument panel
Abrasion, right leg tibia area	1	Instrument panel
Abrasion, left arm	1	Instrument panel
Abrasion, left flank	1	Instrument panel
Abrasion/contusion, left knee	1	Instrument panel
Fracture, right fibula	2	Instrument panel and below
Fracture, left femur	3	Instrument panel and below

This passenger was in a hospital for 13 days. Although an AIS 3 injury was sustained, it was not life-threatening.

Seating location: Left rear
Sex: M
Age: 14
Height: 5 feet 10 inches
Weight: 175
Restraint used: Lap belt (ALR)
Proper use? Yes

This boy was wearing a lap belt with an ALR, a sewn-in latchplate fixed to the retractable webbing, and a pushbutton release type of buckle attached to a short length of webbing. Both webbing components entered the seating area from between the junction of the upper and lower seat cushion. The only compartmental deformation noted was to the lower bench seat cushion, found to be displaced forward approximately 2 inches.

Injuries	AIS	Probable Source
Major abdominal contusion (3 inch x 20 inch)	2	Lap belt
Abrasions, right side abdomen	1	Lap belt
Contusions, lateral left thigh	1	Lap belt
Multiple avulsions, superior mesentery veins	4	Lap belt
Avulsion, superior mesenteric artery	4	Lap belt
Avulsed root of mesentery	4	Lap belt
Avulsion, two sections of small bowel	5	Lap belt
Contusion, scrotum	1	Impact force
Contusions, left hand	1	Compartment sidewall

He survived for approximately 5 hours but died before his internal bleeding could be stabilized. All his injuries, with the exception of a contused left hand, were the result of the lap belt.

Seating location: Right rear
Sex: M
Age: 11
Height: 5 feet 2 inches
Weight: 128
Restraint used: Lap belt (ALR)
Proper use? Yes

This boy was wearing a lap belt with an ALR, a sewn-in latchplate fixed to the retractable webbing, and a pushbutton release type of buckle. Inspection of the interior compartment revealed the lower seat cushion to be displaced forward approximately 2 inches. No other compartmental deformation was noted.

Injuries	AIS	Probable Source
Contusion, nose (septal hematoma)	1	Lower extremities
Bilateral contusions, anterior ribline	1	Lower extremities
Major contusion, lower abdomen	2	Lap belt
Gaping laceration of abdominal muscle	3	Lap belt
Complete avulsion of ileum mesentery	4	Lap belt
Complete avulsion of right colon mesentery	4	Lap belt
Perforation of ileum	5	Lap belt
Perforation of cecum	5	Lap belt
Transection of ileum	5	Lap belt
Transection of cecum	5	Lap belt
Avulsion of mid-sigmoid colon mesentery	4	Lap belt
Serosal degloving of mid-sigmoid colon	4	Lap belt
Fracture, third lumbar vertebra with complete paraplegia	5	Lap belt
Fracture, right thumb	1	Compartment interior

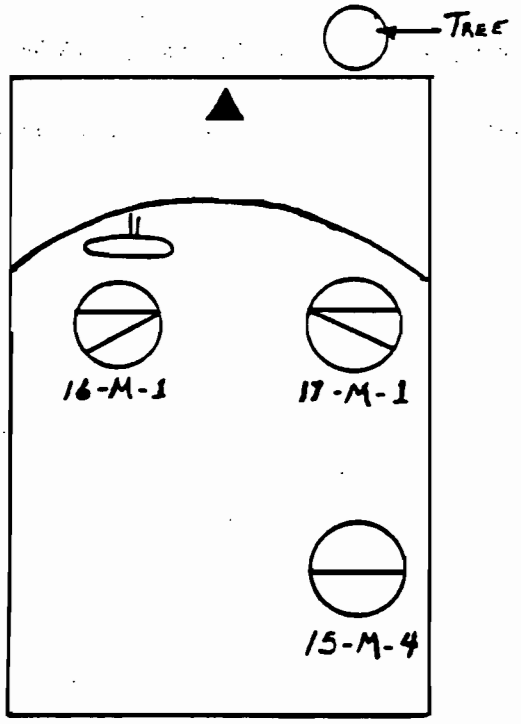
He required 2 months of hospitalization before transfer to an extended care facility for rehabilitation due to the paraplegia.

Both boys lap belted in the rear seat sustained intra-abdominal injuries due to the penetration of that cavity by the lap belts at impact. Descriptive terminology in the left rear passenger's medical records seem to indicate that the lap belt was positioned in the area considered proper. This description places the major belt-related contusion in the lower abdominal region, with related abrasions on lateral aspects of each thigh. The positioning of the right rear passenger's belt, while not as well defined as that of the left rear, also appears to have been proper. The medical description, a transverse contusion, 7-cm wide, at the level of the anterior superior iliac spine, places the belt well within the area considered proper.

Both of the Ford's rear seat passengers underwent their entire deceleration into the 2-inch-wide lap belt. If the crash forces had not been concentrated in this way, but had been spread over a larger area of the body, the severity of these boys' injuries would have been greatly reduced. Lap/shoulder belts would have distributed the crash forces over a wider area of the body.

CASE 27 (SEA-85-H-OR23)

Case vehicle: 1980 Dodge Colt, 2-door
Case vehicle weight: 2,311 pounds
Case vehicle Delta V: 27.7 mph



Circumstances

A 1980 Dodge Colt 2-door sedan struck a tree head-on. The driver was a 16-year-old boy wearing a lap/shoulder belt; the right front passenger was a 17-year-old boy also wearing a lap/shoulder belt; the right rear passenger was a 15-year-old boy wearing a lap belt.

The driver did not receive, nor did he require, any on-scene medical attention. The only injury he reported was a belt abrasion on his left shoulder. However, the two passengers were transported to a hospital. The lap/shoulder belted boy in the right front seat had only minor bruises and was not admitted to the hospital; he was examined and released. The lap belted boy in the right rear seat, however, was admitted with severe injuries; he was hospitalized for 33 days.

Restraint and Injury

Seating Location: Driver
Sex: M
Age: 16
Height: 5 feet 7 inches
Weight: 160
Restraint used: Lap/shoulder belt
Proper use? Yes

This boy was using a continuous loop, lap/shoulder belt with a free-sliding latchplate. There was no evidence of belt malfunction, improper fit, or improper use. He described the fit as "snug." Although the steering wheel was deformed about 2 1/2 inches at the 4 o'clock position, there were no driver injuries that could be related to that deformation. The driver said he had been using seat belts for about 15 months.

Injuries	AIS	Probable Source
Abrasion, left shoulder	1	Shoulder belt

Seating Location: Right front
Sex: M
Age: 17
Height: 5 feet 10 inches
Weight: 135
Restraint used: Lap/shoulder belt
Proper use? Yes

This boy was also using the continuous loop, lap/shoulder belt with a free-sliding latchplate that was provided at his seat. There was no evidence of malfunction, improper fit, or improper use. This boy said that he never wears a seat belt, but that he was "talked into" it on this trip by the rear seat passenger. He was not admitted to a hospital.

Injuries	AIS	Probable Source
Bruise, forehead	1	Instrument panel or A pillar
Strained ankle	1	Floor
Bruise, right shoulder	1	Shoulder belt
Bruise, chest	1	Shoulder belt
Bruise, abdomen (below umbilicus)	1	Lap belt

Seating Location: Right rear
Sex: M
Age: 15
Height: 5 feet 8 inches
Weight: 135
Restraint used: Lap belt (locking latchplate, webbing retractor one unit)
Proper use? Yes

This boy was using a lap belt that has the locking latchplate combined with the webbing retractor in one unit. The retractor automatically takes up webbing slack and the latchplate locks the webbing in place when buckled. There were no defects found in the system. The boy said he was wearing the belt "snug" and that it was routed across the waist but below the navel. He said he had been using seat belts for 12 months before this crash.

Injuries	AIS	Probable Source
Fractured vertebrae (L2, L3)	3	Flexion over lap belt
Perforations (two), small bowel	4	Lap belt and/or retractor
Ruptured spleen	4	Lap belt retractor
Bruise, left hip	1	Lap belt
Bruise, right hip	1	Lap belt
Abrasion, about 1 inch below umbilicus	1	Lap belt

The performance of the front seat lap/shoulder restraints was exceptionally good in this Delta V 27.7 mph crash, especially when compared to the rear seat lap belt. Forces acting at the right front were very similar to those acting at the right rear, allowing a direct comparison of lap/shoulder belt performance to lap-only belt performance. The crash resulted in AIS level 1 injuries at the right front, which required only 1 hour 15 minutes of observation and treatment before that boy was released from medical care. In comparison, the crash induced injuries sustained by the lap belted boy in the right rear position were at an AIS 4 level and required two operations during the course of more than 1 month's hospitalization.

Prompt initial diagnosis and treatment probably would have reduced the period of hospitalization required for the lap belted boy. It appears that, at initial injury evaluation, the attending physician "ruled out" all of the serious injuries that were, in

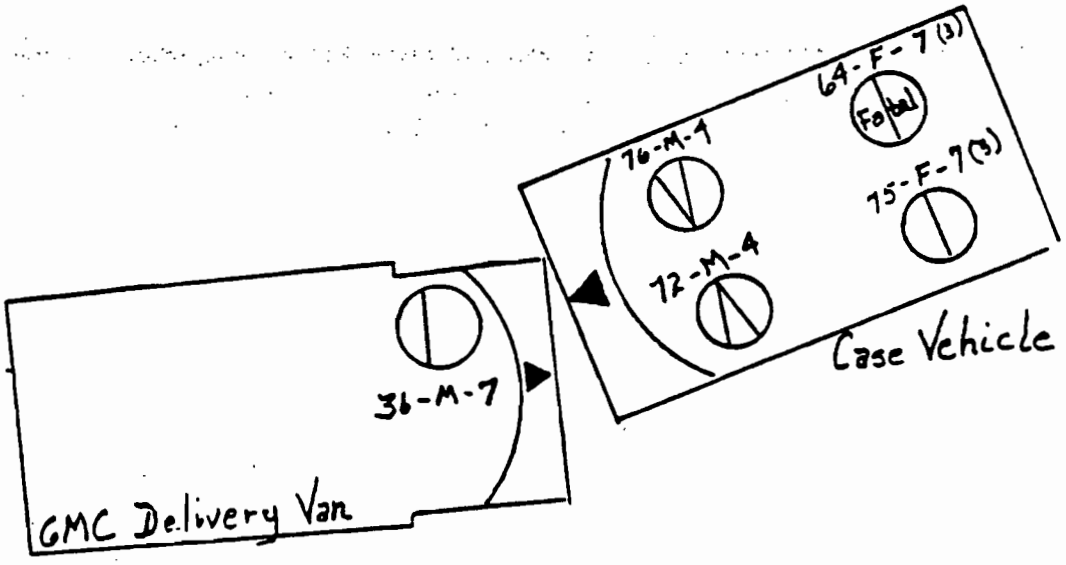
fact, present. As a result, the fractures of two lumbar vertebrae were not identified for at least a day and the major internal organ damage was not identified for nearly 2 weeks following admission to the hospital. From that point, two major operations were required for repair of perforated intestines, severe abscessing, and finally, removal of the damaged spleen.

These internal injuries, and the fractures of the lumbar vertebrae, must be attributed directly to the lap belt used by this boy. It is clear that the major intra-abdominal injuries resulted from compression around the bulky retractor mechanism integral to the latchplate on this system. The design of this component places the retractor directly in the area of all the internal injuries described by the boy's medical records.

If this boy had had available to him, and had been properly wearing, a 3-point lap/shoulder belt, he would not have sustained the spinal injuries or the internal injuries induced by the lap belt.

CASE 28 (SEA-86-H-OR04)

Case vehicle: 1984 Buick Century Custom, 2-door
Case vehicle weight: 3,488 pounds
Case vehicle Delta V: 31.7 mph



Circumstances

A 1982 Buick Century struck front first into the left front of a GMC delivery truck. The Buick was driven by a 72-year-old man wearing a lap/shoulder belt. The right front passenger was a 76-year-old man also wearing a lap/shoulder belt; the left rear passenger was a 75-year-old woman wearing a lap belt; and the right passenger was a 64-year-old woman, also wearing a lap belt.

Both vehicles were disabled by the impact; the Buick received front structural collapse of more than 28 inches.

The collision resulted in unspecified injuries to the lap belted driver of the large truck. Both front seat occupants of the Buick sustained serious myocardial contusions, minor to moderate fractures, and numerous abrasions and contusions. The left rear lap belted occupant sustained injuries to her abdomen, spine, and pelvis which required more than 1 1/2 months of hospitalization and care. The lap belted right rear occupant received injuries to her head, thorax, and abdomen which resulted in her death.

Restraint and Injury

Seating location: Driver
Sex: M
Age: 72
Height: 5 feet 10 inches
Weight: 198
Restraint used: Lap/shoulder belt (ELR)
Proper use? Probably excessive slack due to "windowshade" device

This man was restrained by a 3-point, continuous loop, lap/shoulder belt with an ELR sensitive to vehicle motion, a cinching type of latchplate, and a pushbutton release type of buckle attached to a flexible stalk. A windowshade type of tension relief device was also incorporated into the system. The instrument panel was broken and distorted, with the steering assembly collapsed forward and upward.

Injuries	AIS	Probable Source
Myocardial contusion	4	Steering assembly, shoulder strap
Fractured sternum	2	Steering assembly, shoulder strap
Contusion, across chest	2	Shoulder strap
Fractured toe, right	2	Floor pan, controls
Contusion, right knee	1	Instrument panel
Contusion, left knee	1	Instrument panel
Small lacerations, left hand	1	Instrument panel

This man spent 10 days in a hospital and was released to the care of his personal physician.

It is likely that this man was wearing his shoulder strap with excessive slack by means of the windowshade type of tension relief device, based on the degree of deformation to the steering wheel.

Seating location: Right front
Sex: M
Age: 76
Height: 5 feet 11 inches
Weight: 200
Restraint used: Lap/shoulder belt
Proper use? Yes

This man was wearing a lap/shoulder belt similar to the driver's. It appears likely that he was wearing it properly.

Injuries	AIS	Probable Source
Myocardial contusion	4	Shoulder strap
Fracture, 1st rib, left	1	Impact force
Displaced fracture, left wrist	3	Instrument panel

He required 5 days in a hospital and an unspecified period of outpatient care.

The myocardial contusions sustained by these two lap/shoulder belted men are unusual among the cases investigated by the Safety Board. It is possible that their age contributed to this injury.

Both front seat occupants probably would not have survived if they had not been wearing lap/shoulder belts.

Seating location: Left rear
Sex: F
Age: 75
Height: 5 feet 7 inches
Weight: 170
Restraint used: Lap belt (ALR)
Proper use? Yes

This woman was wearing a lap belt with an ALR, a sewn-in latching tongue attached to the retractable webbing, and a pushbutton release type of buckle attached to a short length of webbing. Both webbing components entered the seating area by passing through the junction of the upper and lower cushions. There was no apparent compression or deformation of the compartment at this position.

Injuries	AIS	Probable Source
Comminuted and displaced fracture, right proximal humerus	3	Compression force
Comminuted nasal fracture	2	Right front seatframe
Bilateral fracture, iliac crests	3	Lap belt
Displaced fracture of spine at L4	3	Lap belt
Retroperitoneal hematoma	3	Lap belt
Blunt abdominal trauma	7	Lap belt
Closed auxiliary nerve injury	7	Unknown
Massive contusion/abrasion lower abdomen	2	Lap belt
Laceration, left iliac crest	1	Lap belt

This woman was in the hospital for 20 days before being released to an extended care facility for an additional 3 weeks of treatment.

With the single exception of the upper arm fracture, all of the injuries sustained by this woman can be attributed directly to the lap belt restraint that was worn. These injuries were considered life-threatening by hospital personnel even after 10 days of care, shown by the orders for transfer with life support equipment on board the ambulance. If she had been wearing a properly fitted lap/shoulder belt, she would most likely not have sustained any of these injuries.

Seating location: Right rear
Sex: F
Age: 64
Height: 5 feet 3 inches
Weight: 165
Restraint used: Lap belt (ALR)
Proper use? Probably, with possible belt "ride up"

This woman was wearing a lap belt similar to the one used by the left rear passenger. There were hairs embedded at various points about the rear surface of the right front seat. Body fluids were found on the lap belt webbing.

Injuries	AIS	Probable Source
Large laceration above right iliac crest	3	Lap belt
Intra-abdominal injury	7	Lap belt
Massive facial injuries	7	Right front seatframe
Large ecchymoses, anterior chest	7	CPR

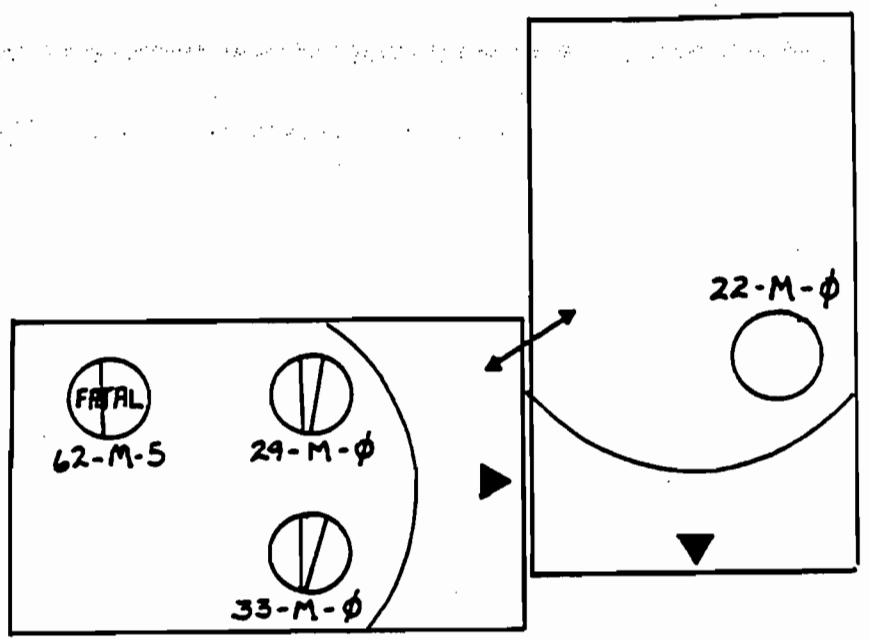
This woman's injuries were evaluated by emergency medical personnel at the accident scene as being "not life-threatening." Her condition deteriorated while enroute to the hospital and she was in full cardiac arrest upon arrival. Revival attempts failed and she was pronounced dead approximately 2 hours after the crash. The medical examiner noted that her death was probably the result of a ruptured great vessel of her heart.

The woman's death probably resulted from injuries sustained as a direct result of the forces transmitted through the lap belt. However, this cannot be stated with certainty, due to the lack of medical information. The forces necessary for fatal intra-abdominal injuries were certainly present, shown by the large gaping laceration completely into her abdominal cavity. Decreasing blood pressure while enroute to the hospital indicates a loss of blood at some point within her system.

This woman almost certainly would have survived if she had been wearing a properly fitted lap/shoulder belt.

CASE 29 (LAX-86-H-OR04)

Case vehicle: 1985 Oldsmobile Firenza, 4-door
Case vehicle weight: 2,968 pounds
Case vehicle Delta V: 25.7 mph



Circumstances

A 1985 Oldsmobile Firenza struck the side of a 1977 Chevrolet Camaro at an intersection. Both vehicles received substantial damage, with rearward structural collapse reaching depths of more than 15 inches at the Oldsmobile front and inward collapse reaching depths of up to 13 inches at the right side of the Camaro.

The unrestrained 22-year-old man driving the Camaro was unhurt, as were the lap/shoulder belted 29-year-old man driving the Firenza and his lap/shoulder belted right front passenger, a 33-year-old man. The 62-year-old man wearing a lap belt in the left rear seat of the Firenza, however, sustained massive intra-abdominal injuries, including multiple lacerations and tears of the small bowel, along with a severe fragmentation fracture of the right iliac wing. This man's injuries proved fatal 39 hours after the crash.

Restraint and Injury

Seating location: Driver
Sex: M
Age: 29
Height: Unknown
Weight: Unknown
Restraint used: Lap/shoulder belt (ELR)
Proper use? Yes

This man was restrained by a 3-point lap/shoulder belt with an ELR sensitive to vehicle motion, a cinching type of latchplate, and a pushbutton type of buckle mounted on a flexible stalk. The system also incorporated a windowshade type of tension relief device.

He sustained no specified injury, other than complaint of "pain."

Seating location: Right front
Sex: M
Age: 33
Height: Unknown
Weight: Unknown
Restraint used: Lap/shoulder belt (ELR)
Proper use? Yes

This man was wearing a lap/shoulder belt similar to that worn by the driver. He also complained only of pain, with no specific injury identified.

Seating location: Left rear
Sex: M
Age: 62
Height: 5 feet 4 inches
Weight: 130
Restraint used: Lap belt (ALR)
Proper use? Yes

This man was wearing a lap belt with an ALR, a sewn-in latchplate attached to the retractable webbing, and a pushbutton type of buckle attached to a short length of webbing. The buckle webbing entered the seating area by passing between the junction of the upper and lower seat cushion, while the latchplate webbing entered from between the lower cushion and interior sidewall. There was no compartment distortion or compression at this seating position.

Injuries	AIS	Probable Source
Fragmented fracture, right iliac wing	3	Lap belt
Torn right iliopsoas muscle	2	Lap belt
Retroperitoneal hemorrhage	3	Lap belt
Complete severance, proximal ileum	5	Lap belt
Large laceration/tear, distal ileum	5	Lap belt
Laceration of omentum	4	Lap belt
Multiple large lacerations, mesentery	4	Lap belt
Gaping tear (1.5 cm), small bowel	5	Lap belt
Extensive contusions, mesentery	3	Lap belt
Contusion, ascending colon	3	Lap belt
Contusion, transverse colon	3	Lap belt
Contusion, descending colon	3	Lap belt
Contusion, right iliac crest	2	Lap belt
Contusion, left iliac crest	2	Lap belt
Contusion, right hip to right flank	2	Lap belt
Contusion, left thigh to knee	2	Interior sidewall
Contusion, left occipital region	2	Interior sidewall

This man was in intensive care for 39 hours at two hospitals before he died from his injuries. A laparatomy was performed approximately 4 hours after his initial admission to a hospital; however, no additional surgery was undertaken, even though blood pressure could not be maintained at adequate levels. At autopsy, approximately 4,000 grams of blood clots were found within his abdominal cavity due to intra-abdominal hemorrhaging. In addition, the autopsy noted hemorrhagic material within his stomach and fecal matter within his abdominal cavity. A blood clot of approximately 300 grams was found in the liver area.

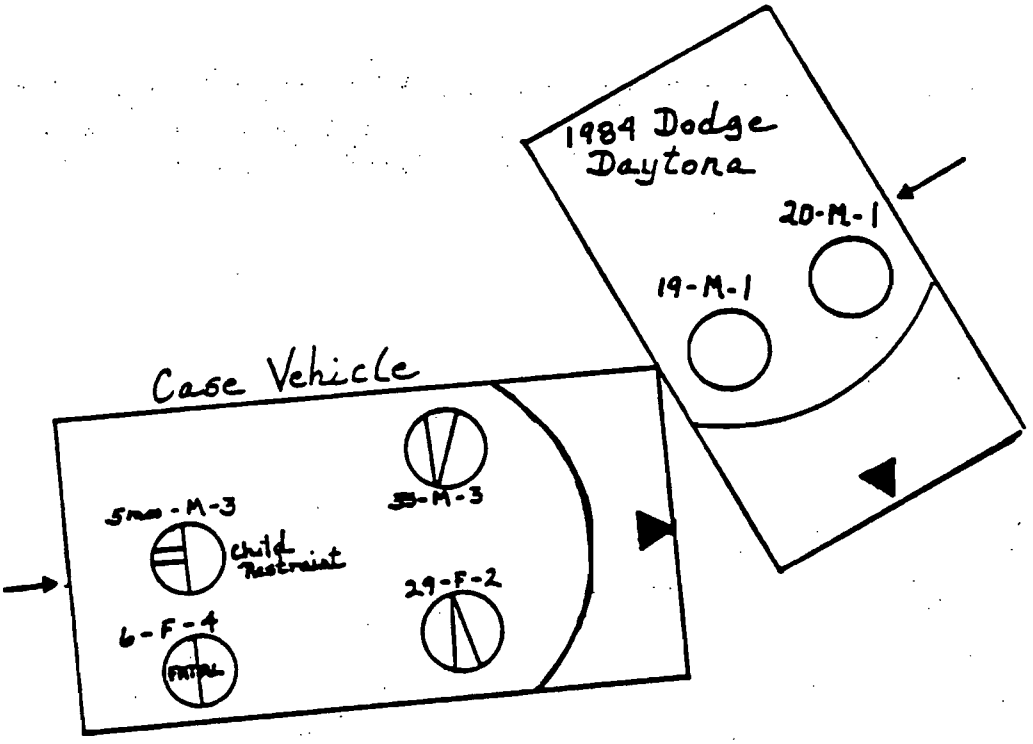
This man might have survived if he had been transported initially to a special trauma center. The physicians attending him did not locate the cause of his post-operative lack of adequate blood pressure and undertake its correction. Furthermore, there is evidence that the surgical measures taken to treat his internal injuries were not appropriate. For example, a consulting surgeon told Safety Board investigators that a physician trained in trauma injury treatment would have operated sooner, would not have repaired the bowel tears by stapling (the bowel leakage may have been due to this inappropriate treatment), and if the bowel leakage had continued, would have performed a second operation to correct it. This doctor said that the "resuscitative effort" expended for this man was "poor."

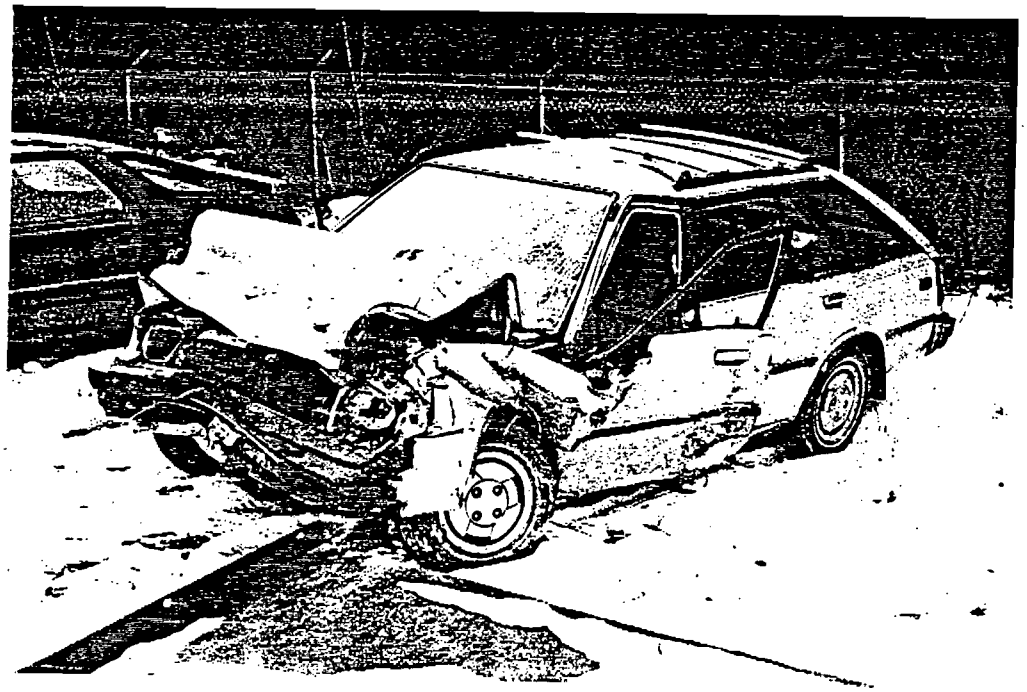
From the injuries indicated in hospital and autopsy records, it seems likely that the lap belt rose above this man's left iliac crest during the crash and penetrated the abdominal cavity from left to right. This interpretation is based on the nature and location of his bowel injuries and the fact that his right iliac crest was displaced rearward and outward. The path of his injuries is consistent with the reactive travel path of his body within the vehicle, given the dynamics of the collision: he would have moved forward and to the left. Evidence suggests that there was a lifting action at the Oldsmobile's left front, which would have induced a downward force at this man's seating position. Thus, the reactive forces at his position would have been directed downward, forward, and to the left--leading to the types of belt induced injuries he sustained.

This man would have survived, with much reduced injuries, if he had been wearing a properly fitted lap/shoulder belt.

CASE 30 (NYC-85-H-OR04)

Case vehicle: 1984 Nissan Sentra station wagon
Case vehicle weight: 2,330 pounds
Case vehicle Delta V: 33.6 mph





Circumstances

A 1985 Dodge Daytona 2-door sedan slid broadside into the front of a 1984 Nissan Sentra station wagon. The Dodge was driven by an unrestrained 20-year-old man; in the right front seat was an unrestrained 19-year-old man. The Nissan was occupied by a 33-year-old male driver and his 29-year-old wife, both of whom were using 3-point lap/shoulder belts; in the rear center seat was their 5-month-old boy in a child safety seat, and in the right rear seat was their 6-year-old daughter, using a lap belt.

After the crash, the occupants of both vehicles were taken by ambulance to a hospital. The unrestrained Dodge occupants were treated and released within a few hours, having sustained only minor injuries. The Nissan driver and his 5-month-old son sustained serious injuries; the children's mother sustained moderate injuries. The 6-year-old child was killed by lap belt induced injuries.

Restraint and Injury

Seating location: Driver
Sex: M
Age: 33
Height: 5 feet 10 inches
Weight: 160
Restraint used: Lap/shoulder belt (ELR)
Proper use? Yes

This man was wearing a continuous loop lap/shoulder belt with a free-sliding latchplate and ELR. There was no evidence that the restraint failed or was defective.

Injuries	AIS	Probable Source
Severe depressed complex fracture of left zygomatic maxillary	3	Left A pillar
Abrasion, left shoulder	1	Shoulder belt
Abrasion, left chest	1	Shoulder belt
Abrasion, sternum	1	Shoulder belt
Hematoma, right ankle	No Code	Unknown

At impact, the vehicle underwent sudden deceleration and counterclockwise rotation. Due to inertia, the occupants tended to continue moving forward, and they also moved leftward in relation to the vehicle's interior. Since all the occupants were restrained, their movement was limited to varying degrees. The adults in the front seat apparently experienced the least movement: their upper torsos and pelvic areas were effectively restrained by their lap/shoulder belts and, except for the left side of the driver's face, there were no other vehicle contact injuries reported. Had the front seat occupants not been properly restrained by lap/shoulder belts, they probably would have been critically injured.

Seating location: Right front
Sex: F
Age: 29
Height: 5 feet 2 inches
Weight: 105
Restraint used: Lap/shoulder belt
Proper use? Yes

This woman was wearing a lap/shoulder belt similar to that of the driver; there was no evidence of restraint failure or defect.

Injuries	AIS	Probable Source
Displaced fracture, right clavicle	2	Shoulder belt
Fractured rib, 1st right side	1	Shoulder belt
Fractured ribs, 5, 6, 7, and 8, left side	2	Shoulder belt
Contusions, left and right iliac crests	1	Lap belt
Contusions, from right clavicle to left mid-sternum	2	Shoulder belt

(See discussion above.)

Seating location: Center rear
Sex: M
Age: 5 months
Height: 23 inches
Weight: 15 lbs. 8 oz.
Restraint used: Child safety seat
Proper use? No

This infant was seated in a child safety seat; however, it was improperly installed, with the car's static lap belt routed through the lower part of the safety seat's tubular frame, rather than around the front of the entire seat, as it was supposed to be.

Injuries	AIS	Probable Source
Depressed skull fracture of left frontal bone	3	Left rear windowframe
Linear fracture, left parietal bone	2	Left rear windowframe
Abrasion, contusion, left cheek and around left eye	1	Left rear windowframe
Hematoma, left orbital area	No Code	Left rear windowframe

Although seated in a child safety seat, this child struck his head on the left left rear window frame because the improper routing of the vehicle's lap belt through the lower part of the safety seat permitted the seat to pitch forward and leftward at impact. Had the child seat been properly installed, its movement would have been considerably reduced and the child would not have contacted the window frame.

Seating location: Right rear
Sex: F
Age: 6
Height: 41 inches
Weight: 50
Restraint used: Lap belt (ALR)
Proper use? Belt routing may have been high

This child was wearing a static lap belt with an ALR. During the crash, the seat cushion was displaced forward about 1 inch.

A photograph of the child's abdomen shows a deep bruise across the area, slightly above the iliac crests but below the umbilicus. These marks indicate that at peak loading, the lap belt was above the iliac crests, above the area considered to be proper fit.

Injuries	AIS	Probable Source
Contusion, abrasion of forehead	2	Unknown
Linear fracture of frontal bone	2	Unknown
Contusion, right frontal cerebral cortex	3	Unknown
Occipital/cervical dislocation	2	Unknown
Laceration, occipital/cervical ligaments, transection of vertebral arteries	3	Unknown
Contusion, abrasions, anterior abdominal wall	2	Lap belt
Laceration of mesentery	3	Lap belt
Intraperitoneal hemorrhage	No code	
Unconscious	4	Unknown

At impact, the upper torso of this child pitched forward and downward over the lap belt, and the child's head struck the vehicle's interior. Although no evidence identifying the contact point was found, it is suspected, based on the child's head injuries, probable kinematics, the seat cushion softness, and the child's size, that her head struck the forward edge of the metal platform near the floor, on which the rear seat bottom cushion rests.

The pathologist listed the cause of this child's death as the dislocation of the occipital/cervical junction and resulting injuries to the vascular supply to the base of the brain. He believed that these injuries most likely resulted in death within a few minutes. The frontal skull fractures and serious intra-abdominal injuries may have contributed to her death, but he regarded the head/neck separation as the primary cause of death.

Based on a comparison of the injuries to the several occupants, it is clear that the lap belt did not provide the level of protection that the lap/shoulder belts provided. Furthermore, the lap belt in this case probably contributed to the development of the child's fatal head injuries, rather than preventing them. Since the injuries that proved fatal to this child were most likely those to her head and neck, not those to her intra-abdominal viscera (serious as those were), her death cannot be attributed to improper belt placement; the jackknifing motion over the lap belt that resulted in her head strike would have occurred even if the belt had been placed slightly lower on her abdomen.

While there is insufficient evidence to predict what injuries she would have received had she been unrestrained, there is sufficient evidence to conclude that she almost certainly would have survived had she been restrained by a lap/shoulder belt.

APPENDIX B

CANADIAN CASES CONCERNING REAR SEAT LAP BELTS

C 1

A 1978 Pontiac Laurentian hit the side of a 1977 Monte Carlo Landau pulling a small (150 pound) trailer. All four belted occupants of the Pontiac died of their crash injuries.

The 70-year-old man driving the Pontiac weighed 155 pounds and was five feet, 10 inches tall. He was wearing a three-point lap-shoulder belt; it is not recorded whether he wore it correctly. The lap belted woman sitting behind him crashed into the back of his seat. The cause of his death was rupture of the spleen.

The right front passenger was a 65-year-old man, five feet, ten inches tall, 200 pounds. He was wearing a three-point lap-shoulder belt. Again, it is not recorded whether he wore it correctly. The lap-belted woman sitting behind him crashed into the back of his seat. The cause of his death was fracture of his spine. He also sustained head and face injuries.

The left rear passenger was a 57-year-old woman, five feet, three inches tall and weighing 155 pounds. She wore a lap-only belt; it is not recorded whether it fit her properly. She sustained fatal intra-abdominal injuries and injuries to her extremities.

The right rear passenger was also a 57-year-old woman, five feet, two inches tall and weighing 165 pounds. She also wore a lap-only belt and suffered injuries to her extremities and fatal intra-abdominal injuries.

C 2

In this crash, a 1982 Pontiac Phoenix impacted a "large mid-70's sedan" head-on. The Pontiac was reported to be moving forward at about 34 mph at impact; the speed of the other vehicle is not recorded.

The record does not state how many people were traveling in the Pontiac, nor whether they were wearing belts. It does state that the only person injured in the Pontiac was a man, 157 pounds, five feet, eight inches tall, wearing a lap-only belt. His seating location is not recorded. He sustained intra-abdominal injuries and fracture of the third lumbar vertebra.

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* Information on these cases was provided to the Safety Board by Transport Canada. In transmitting this information, the Canadian officials noted that "the extent to which the accident cases which have been compiled are necessarily representative of frontal collisions resulting in abdominal injury to a lap-belted individual is largely unknown."

C 3

On April 25, 1980, a 1978 Plymouth Horizon struck the right front of a "late model, mid-size American vehicle." Three people were traveling in the Plymouth: a 67-year-old man driving (six feet tall, 207 pounds), wearing a three-point lap-shoulder belt; a 65-year-old woman in the rear seat behind him (left rear), five feet, three inches tall, 154 pounds, wearing a lap-only belt; and a 67-year-old woman in the right rear seat (height and weight unrecorded), wearing a lap-only belt.

The driver died three days after the crash, of intra-abdominal injuries; he had also sustained chest injuries. The left rear passenger died of "extensive abdominal injuries." Her fourth lumbar vertebra was also fractured. Although at first the injuries of the right rear passenger were thought to be the most severe, she survived her serious intra-abdominal injuries (she spent 15 days on a respirator, however).

There were no serious head injuries to any of the three occupants. The investigator judged the crash to have been "survivable". The coroner noted in his report that "if /rear/ seat belts were designed in a different fashion to hold either the legs or the pelvis and also the trunk in position, the injuries would be less serious. . . . Having seen the results of the injuries at first hand at the accident site . . . and at the operation of /right rear passenger/, I feel strongly that seat belts can be redesigned."

C 4

On July 24, 1982, a 1979 Plymouth Horizon struck a bridge abutment with the right front of the car. The car was reported to have been traveling at about 40-50 mph when it left the travelway. The car was being driven by a 44-year-old man who was wearing a three-point lap-shoulder belt. He received "minor" injuries, apparently only "small bruises."

In the right front seat was a 30-year-old woman wearing a three-point lap-shoulder belt. She received what are recorded as "minor" injuries, including a "deep cut" to one arm, "loss of teeth," a laceration of the chest.

In the left rear seat (behind the driver) was a 67-year-old woman wearing a lap-only belt. Two of her ribs were fractured in the crash.

In the right rear seat was a 12-year-old boy wearing a lap-only belt. He sustained a "minor skull fracture" and serious intra-abdominal injuries, including perforation of the small bowel and two lacerations of the mesentery.

C 5

In early November 1981, a 1976 Oldsmobile Cutlass with four occupants crashed head-on with a 1978 Ford van. The severity of the crash is not recorded. The Cutlass driver was a 23-year-old man weighing 150 pounds. It is not recorded whether he wore a seat belt. He received "serious" chest injuries, probably from violent contact with the steering system. The lap-belted woman seated behind him crashed into the back of his seat during the impact.

The right front passenger was a 55-year-old man weighing 150 pounds. He was wearing a three-point lap-shoulder belt. He sustained injuries to his head and face and fatal chest injuries. The investigator stated that the "seat belt webbing broke under impact at head rest holding clip level."

The left rear passenger (behind the driver) was a 48-year-old woman, five feet, four inches tall, who weighed 140 pounds. She wore a lap-only belt. She sustained injuries to her face, bilateral fractures of six lower ribs, a fractured spine at the second lumbar vertebra. Her spine also separated 10.5 cm at the fracture point; this separation was deemed the cause of death.

The left rear passenger was a 20-year-old man, five feet, ten inches tall, who weighed 150 pounds. He wore a lap-only belt. His skull was fractured, he sustained multiple bilateral rib fractures, and his distal lumbar spine was displaced to the right by half its diameter. He died of the spine dislocation. The investigator suggested that this man may have "submarined" under the belt during the crash.

C 6

In this crash, the right front of a 1981 Honda Accord hit the left rear tire of a parked 1975 John Deere back hoe. The Accord was said to be traveling at about 18 mph when it hit the parked vehicle.

The driver was a 69-year-old man, five feet, five inches tall, who weighed 240 pounds and who was wearing a three-point lap-shoulder belt. He sustained a minor (AIS 1) sprain of his right hip.

The right front passenger was a 68-year-old man, five feet, four inches tall, who weighed 180 pounds and who was wearing a three-point lap-shoulder belt. He sustained minor (AIS 1) bruising of his right shoulder, chest, and abdomen.

The left rear passenger (behind the driver) was a 58-year-old woman, five feet tall, who weighed 180 pounds and who wore a lap-only belt. She sustained serious (AIS 3) injuries to her abdominal wall.

The right rear passenger was a 64-year-old woman, five feet, one inch tall, who weighed 190 pounds and who wore a lap-only belt. She received head and abdominal injuries: a two-inch laceration of the right temple with "massive resultant hematoma," severe bruising across the abdomen above the iliac crests, and "massive intraperitoneal hemorrhage caused by multiple injuries to the abdomen and contents." The intra-abdominal injuries were fatal.

This was a moderate crash which, according to the investigator, "should have been survivable" for this passenger, especially "considering the /minor/ injuries incurred by the front seat occupants." There was "no evidence to indicate the /rear seat/ occupants submarined the lap belts" in this crash; the investigator concluded from the evidence that the lap belt worn by the right rear passenger was at or above the iliac crests at the time of the impact. Whether it was possible for this passenger to wear the lap belt provided in this car in a lower position is not discussed.

The investigator also stated that if the rear seat occupants had been unrestrained they probably could have survived this crash, although the restrained front seat occupants might have been more seriously injured in that case. The "installation of combination lap and shoulder /belts/ in the rear seat in /all/ likelihood would have reduced the /rear seat occupants'/ injuries to minor ones," the investigator stated. He noted that, beginning with the next year's model, Honda Accord did provide such rear seat lap-shoulder belts.

C 7

This crash was also classified as "moderate." A 1981 Toyota Corona hit a 1952 Ford pickup, left front to left front. The driver (whose seating location was in direct line with the principal point of impact) was a 63-year-old man, five feet, six inches tall, weighing 140 pounds. He was wearing a three-point lap-shoulder belt; his arms and legs were fractured and one hip dislocated.

The right front passenger was a 63-year-old man, of the same height and weight as the driver and also wearing a three-point lap-shoulder belt. He sustained minor (AIS 1) bruises.

The left rear passenger (behind the driver) was a 63-year-old woman, five feet tall, weighing 90 pounds, and wearing a lap-only belt. She sustained minor (AIS 1) bruises and a sprained ankle.

The right rear passenger was a 68-year-old woman, six feet tall, weighing 170 pounds, and wearing a lap-only belt. The investigator said she was wearing the belt correctly, low on the abdomen and snug. She sustained severe bruising across the lower abdomen, abrasions over both the left and right iliac crests, head injuries ("extensive subarachnoid hemorrhage"), fractures of the third and fourth lumbar vertebrae, multiple severe intra-abdominal and intra-thoracic injuries. She died of "massive hemorrhaging from a torn abdominal aorta."

Lap belt cases from the Transport Canada "Fully Restrained Occupant Study" (FROS):

Case 0119

This crash involved a 1976 Plymouth Volare; it was classified 12 FDEW 3.(*) The driver was a 56-year-old woman, five feet, two inches tall, weighing 182 pounds, and wearing a three-point lap-shoulder belt. The investigator concluded that she was wearing the belt correctly. She sustained serious injuries (AIS 3): fractures of the third and fourth ribs on the left, left pneumothorax, bruising at the waist, a lacerated knee, and a fracture of the left wrist. She probably received her torso injuries from contact with the steering wheel, intensified by the fact that the two lap-belted rear seat occupants crashed into the back of the front seat.

The right front passenger was a 68-year-old woman, five feet, two inches tall, weighing 150 pounds and wearing a three-point lap-shoulder belt. It is not recorded whether she wore the belt correctly. She also was subjected to the overloading of the front seat back caused by the lap-belted rear seat occupants. She sustained a ruptured spleen (AIS 4), ruptured bowel (AIS 5), and fractured vertebrae (AIS 3).

The left rear lap-belted passenger was a 78-year-old woman, four feet, 11 inches tall, weighing 160 pounds. She sustained belt-induced injuries: ruptured bowel (AIS 5), two tears of the small bowel mesentery (AIS 5), lacerations of the spleen (AIS 4), fractured fifth, sixth, seventh, and eighth left-side ribs (AIS 3), fractured right wrist (AIS 2), comminuted fracture of the right tibia (AIS 2), fractured nose (AIS 1), and contusions at the abdomen (AIS 1).

The right rear lap-belted passenger was a 76-year-old woman, five feet tall, weighing 180 pounds. She sustained facial, chest, intra-thoracic, spinal, intra-abdominal, and extremities injuries: a ruptured diaphragm, complete transections of the sigmoid colon and small intestine, ruptured aorta, ruptured iliac arteries, bilateral hemothorax, bilateral rib fractures, fractured thoracic vertebra, fractured sternum, fractured nose, and abrasions and contusions of the abdominal wall. She died of her injuries. Her facial and upper torso injuries were probably caused by violent contact with the back of the front seat, the intra-thoracic and intra-abdominal injuries by high loading from the lap belt.

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* This code is from the Collision Deformation Classification system, widely used by motor vehicle crash investigators to classify crashes according to the principal direction of force, location and extent of contact damage, etc. It does not denote severity in terms comparable to such designations as Delta V (used by the Safety Board in its crash investigations), although accomplished interpreters can deduce severity to some extent from the code. It is not readily translatable into terms accessible to lay readers but may be of significance to technical readers and is included here for that reason.

Case 0152

This crash, classified 12 FDEW 3, involved a 1976 Datsun B210. In this case, the investigator concluded there was no loading of the front seat back by the rear seat occupant, there was no intrusion that would account for the occupants' injuries, and the driver did not violently contact the steering assembly.

The driver was a 71-year-old woman, five feet, three inches tall, weighing 165 pounds. She wore a three-point lap-shoulder belt; although she apparently was using the "comfort clip" tension reliever, the investigator concluded she wore the belt system "snug." She received serious injuries that required 18 days' hospitalization: a "large" laceration of the forehead, contusion of the upper left chest, a "sore neck," and a "deep laceration" of the left knee. The overall AIS rating of these injuries was 3 (serious).

The right front passenger was a 20-year-old woman, weight and height unrecorded. She wore a three-point lap-shoulder belt, but it is not indicated whether she wore it correctly. She did not, apparently, use the "comfort clip" tension reliever. She sustained only minor injuries (AIS 1): an abrasion across the right shoulder, sternum, and left breast. She suffered "neck pain."

The right rear passenger was a 16-year-old woman, weight and height unrecorded. She wore a lap-only belt. She survived a severed ureter (AIS 3), a compression fracture of the second lumbar vertebra (AIS 2), forehead abrasions (AIS 1), bilateral contusions of the abdominal wall (AIS 1), and a contusion below the left knee (AIS 1).

Case 0174

This crash of a 1973 Ford LTD was classified 12 FYEW 4. The driver, a 17-year-old man, six feet, three inches tall and 195 pounds, was wearing his three-point lap-shoulder belt. It is possible that the shoulder portion had excessive slack in it. He spent nine days in the hospital beginning recovery from a fractured right upper tibia (AIS 2), a laceration of the right knee (AIS 2), a comminuted fracture of the nose (AIS 2), fractured left rib (AIS 2), and an abrasion of the left forearm (AIS 1).

The right front passenger was a 16-year-old man, five feet, eight inches tall, 125 pounds, wearing a three-point lap-shoulder belt (he also may have worn the shoulder portion loosely). He was in hospital for six days, having sustained minor and moderate facial fractures (AIS 1 and 2), an AIS 2 compression fracture of the fifth lumbar vertebra, and an AIS 1 forehead laceration.

The right rear passenger was a 17-year-old man, six feet tall, 145 pounds, wearing a lap belt. The investigator concluded that he wore the belt snugly; the belt may have crossed his abdomen at or above the iliac crests, though this is not certain. He spent 49 days in the hospital, beginning recovery from critical intra-abdominal injuries: laceration of the caecum (AIS 5) and laceration of the mesentery (AIS 3). He also sustained an AIS 2 compression fracture of the fourth lumbar vertebra and an AIS 1 contusion of the lower abdominal wall.

Case 0150

This case involved no loading of the front seatback by the rear seat occupant, no injurious intrusion, no injurious contact by the driver with the steering system, and the rear seat occupant reportedly wore the lap belt correctly. The crash involved a 1976 Chevrolet Nova and was classified 12 FRES 9.

The driver was a 31-year-old man, five feet, eight inches tall, 125 pounds, wearing his three-point lap-shoulder belt correctly. He sustained minor bruising of his chest and ankle and was not hospitalized.

The right front passenger was a 33-year-old woman, five feet tall, 115 pounds, wearing her three-point lap-shoulder belt correctly. She sustained moderate brusing of the left hip and a fractured rib on the left side. She was not hospitalized.

The right rear passenger was a 52-year-old woman, five feet, four inches tall, 122 pounds, wearing a lap-only belt correctly. She was hospitalized for four days, having sustained facial bruising (AIS 1) and moderately severe (AIS 2) lower abdominal wall bruising.

Case 0153

This case involved a crash of a 1976 VW camper and was classified as 12 FYEW 7. The driver was a 38-year-old man, height and weight unrecorded. He was unrestrained. There was severe intrusion into his seating location. He sustained a comminuted fracture (AIS 3) of the left femur, a fracture of the left wrist (AIS 2), facial bruising, lacerations, and fractures (all AIS 1), chest bruising (AIS 1), and lacerations and abrasions of the left thigh (AIS 1).

The right front passenger was a 34-year-old woman, height and weight unrecorded. She was correctly wearing her three-point lap-shoulder belt. There was severe intrusion at her seating location also. She sustained a fracture in the left leg (AIS 2), a fracture in the left ankle (AIS 2), minor bruising.

The left rear passenger (behind the driver) was a 35-year-old woman, weight and height unrecorded, wearing a lap-only belt. The investigator concluded that not only was she wearing the lap belt correctly (snug and low) and sitting erect at the time of impact, but also that the lap belt did not "ride up" over the iliac crests during the crash. Nevertheless, she sustained critical head, spinal, and intra-abdominal injuries: brain contusion (AIS 5), dislocation of the third and fourth lumbar vertebrae (AIS 5), complete transection of the lumbar spine (AIS 5), ruptured duodenum (AIS 5), concussion (AIS 5), and fracture of the skull on the right side (AIS 4). She died of her injuries.

The right rear passenger was a 32-year-old woman, weight and height unrecorded (at autopsy she was found to be "obese"), wearing a lap-only belt. The investigator concluded that it was possible the belt was above the iliac crests at the time of impact. She sustained a complete transection of the abdominal aorta (AIS 5), a complete transection of the caecum (AIS 5), a complete transection of the ureter (AIS 3), partial transection of the spine (AIS 5), dislocated vertebrae (AIS 5), lower abdominal hemorrhaging (AIS 5), and bruising of the abdominal wall (AIS 2). She died of her injuries.

APPENDIX C

SELECTED CASES FROM MEDICAL LITERATURE ON LAP BELT INDUCED INJURIES

Aiken, D.W. (1963). Lap belt-induced jejunal perforation of the small intestine. Undetected for 6 days after crash. Injury probably caused by sudden compression between belt buckle and spinal column. Only external indication of belt injury was welt across lower abdomen, below umbilicus. Probable correct belt use, no submarining.

Backwinkel, K.D. (1968). Reports 2 cases. Case 1: A 61-year woman in rear with lap belt; frontal impact, followed by right lateral. Belt bruising across abdomen seen initially, accompanied by complaints of abdominal pain, but condition seemed stable until next morning, when severe pain developed and woman went into shock. At laparotomy, a tear in the mesentery of the small bowel was found, with about 12" of gangrenous bowel. Generalized peritonitis was present and the woman died on the operating table. Case 2: A 19-year man in "high speed" frontal hit, wearing lap belt in right front seat. Driver ejected, fractured nose. Lap belt wearer had extensive multiple laceration of scalp, upper/lower lips, requiring emergency surgency. 20" x 20" area of abrasion and ecchymosis corresponding to seat belt dimensions across lower abdomen, right across left and right iliac crests (indicates correct belt placement). Fracture of third lumbar vertebra. Abdominal distention, no blood at 4-quadrant tap. At laparatomy, however, 750 cc of old blood found, along with perforation of ileum, large tear in mesentery of small bowel, which extended down to inferior mesenteric vein. Also, incomplete tear of ileocolic artery. A 15-cm length of sigmoid colon was "completely stripped of its external coat of serosa, muscularis propria, submucosa, and muscularis mucosae."

Blumenberg, R.M. (1967). Reports 20 cases of "intra-abdominal visceral and mesenteric trauma due to the seat belt syndrome" in the literature at that time. Reports a new case: 25-year lap belted man involved in an approximate 35 mph lateral skid into pole. Received facial lacerations, contusions of the lower abdominal wall at the iliac crests (indicates proper belt placement). Discharged from hospital. 3 days later, abdominal distention and cramping appeared. Internal inspection found a linear tear of the mesosigmoid "extending to its root, and avulsion of the mesentery of a 4-inch segment of redundant sigmoid." Also, a 2-cm performation on the mesenteric aspect of sigmoid. Required 6 weeks in hospital.

Cocke, W.M., J. and Meyer, K.K. (1963). Reports case involving frontal crash into side of another vehicle at estimated 35 mph. Unbelted driver said to have received no injury. A 62-year woman at right front, lap belted (overweight), showed a reddened band on the upper abdomen but no other symptoms noted. 5 hours later, went into shock. The spleen was "severely ruptured," required removal. Also fractured ribs.

Dajee, H. and MacDonald, A.C. (1982). Discusses 27-year woman admitted to hospital with "noticeable seat belt abrasion across the abdomen." Complained of "severe abdominal pain," was pale, with heart rate 120, blood pressure of 70/40 mm Hg. Abdominal distention with tenseness and rebound tenderness. No bowel sounds. At laparatomy, the peritoneal cavity found "filled with food fragments and blood." Transection of stomach, avulsion of the left colonic mesentery and several small bowel serosal lacerations with areas of contusion of the peritoneum and mesentery. She had lost considerable blood.

Doersch, K.B. and Dozier, W.E. (1968). Reports 3 cases of lap belt-induced injury, all in "head-on" collisions. Case 1: 45-year man. Fractured ankle, multiple facial and head injuries. Lower abdominal contusions, abrasions, and ecchymoses. Audible peristalsis, no rebound tenderness of abdomen. Abdominal bleeding noted after catheter had been in place for 8 hours. Laparotomy undertaken 12 hours after accident. Found "large mesenteric laceration beneath a 15-inch segment of infarcted ileum." Case 2: 20-year man sustained compression fracture of 4th lumbar vertebra, multiple facial fractures and lacerations. Abdominal tap was negative, no bowel sounds. Laparatomy undertaken 10 days after accident. Found 2 perforations of cecum with surrounding abscesses. Mesenteric tears and hemoperitoneum. Victim required a "very prolonged convalescence." Case 3: 23-year woman sustained facial fractures and lacerations, fractured right ankle and fracture of the fifth lumbar vertebra. Multiple abdominal contusions and abrasions, "severe 'seat belt sign.'" No abdominal spasm or rebound tenderness. Peristalsis. Hunger. Left femoral pulse moderately diminished. Abdominal taps negative twice. Began deteriorating on day 2. At surgery, found "both rectus muscles, including their sheaths, as well as their adjacent oblique musculature, were completely transected." Peritoneum torn, one continuous abscess cavity from peritoneal space into the muscles and subcutaneous tissues on each side lower abdomen. Small bowel almost completely transected. Two large mesenteric lacerations and traumatic thrombosis of left iliac artery with dissection of intima. Patient died one week later of "overwhelming sepsis."

DuBois, E.F. (1952). Reports 23 cases of intra-abdominal injuries sustained by lap belted aircraft occupants, along with 32 cases of contusions along the belt line.

Fish, J. and Wright, R.H. (1965). Presents 4 cases of lap belt-induced injuries from air crash. Case 1: Arrived hospital in shock. Bruises across lower abdomen and pelvis. Abdomen tense, tender. Paracentesis in 3 quarters was negative. found 2-foot segment of ileum avulsed from its mesentery; small seromuscular tear midportion of the intestine. Avulsed end of mesenteric artery actively bleeding. Hematoma in left transverse mesocolon; spleed had capsular tear near inferior pole. Case 2: Shortly after crash, noted pain in right flank and lower abdomen. Examination found lower abdominal wall and right flank contusions corresponding to areas of pain. Paracentesis in 4 quadrants all negative. In hospital, complained of abdominal discomfort, ate little, had low grade fever to the 13th post-injury day. Exploratory operation found proximal ileum partially transected, adjacent bowel markedly contused; the injured bowel was adherent to the left side. Case 3: This man "extracted himself without difficulty from the wreckage." Only complaint at hospital was lower abdominal and flank pain corresponding to contusions from belt. Able to eat, had normal bowel movement following day. During next 3 days, developed abdominal distention and nausea. Abdominal X-rays showed dilated loops of small intestine. Abdominal exploration on 9th post-injury day found lacerated proximal ileum adjacent to urinary bladder, with considerable surrounding inflammatory reaction. Also, large tear in mesentery. Case 4: Arrived hospital in shock, died within 1 hours. Autopsy showed "wide band of contusions across the lower abdominal wall corresponding to the seat belt. Peritoneal cavity and retroperitoneal space filled with blood. Large segment of small intestine and segment of sigmoid colon avulsed from mesentery. Hemorrhage secondary to laceration of mesentery determined to be cause of death."

Fletcher, B.D. and Brogdon, B.G. (1967). 21-year driver of "small, foreign sports car" struck rear of semitrailer "at a high rate of speed." She "flexed acutely over the seat belt and struck her face against the dashboard." Multiple hematomas of lower limbs, laceration and fracture of nose. "No abdominal contusions, hematomas, or abrasions were noted." Transverse fracture of third lumbar vertebra; also small compression fracture of anterosuperior margin of vertebra body."

Gerritsen, R. et al (1966). Reports 2 cases, both "obese" women in "head-on" collisions, said to be wearing lap belt "loosely." Case 1: Passenger in left rear. At surgery, revealed laceration of jejunum, multiple lacerations of mesentery, traumatic amputation of lower half of omentum. Case 2: Passenger in right rear. At surgery, found to have 3,000 cc of blood in abdominal cavity with lacerations of mesenteric attachment of small bowel, laceration of ileum and cecum, division of ileocecal artery, and tear in serosa of sigmoid colon.

Howland, W.J. et al (1965). 19-year male driver (5'9", 150 lb.) in estimated "80 mph, head-on" collision with steel pole. Said to be wearing belt "loosened." Remained conscious. Low back, neck, left hand pain. Facial lacerations. Numerous upper chest contusions, neck contusions and abrasions. Large hematoma in muscles both sides of midlumbar. Transverse fracture of third lumbar vertebra. Attributed injuries to "seat belt's acting as fulcrum, over which vertebral body was split transversely into two parts; the mechanism was similar to breaking a stick over one's knee."

Hurwitt, E.S. and Silver, C.E. (1965). Young woman, right front passenger, involved in ran-off-road crash into abutment at high speed. Received facial injuries, fractured vertebrae, subluxation of fourth lumbar over fifth lumbar vertebra. White striae over both iliac crests "which conformed to the region of distribution of the seat belt over this area at the time of injury." 16 months after crash, a large hernia, containing colon, small bowel, and stomach, developed in the left upper quadrant of abdomen. (Cf. Case 1 in LeMire et al.)

Kulowski, J. and Rost, W.B. (1956). Said to be first report of a case in which crash injury was attributed to a lap belt. Belt-induced trauma to segment of ileum; later, fibrous adhesion of the terminal ileum to the right iliac crest developed, causing obstruction of the distal part of the small bowel.

"Lap seat belt useful but can injure children," AMA 245:2281 (1981). Reports findings by orthopedic surgeon in 7 cases of serious lap belt-induced injuries among children 9 to 15 in Ontario auto crashes 1977-79 (after Ontario's mandatory belt use law in effect). All riding in rear seat, in frontal collisions. Three sustained torn posterior ligaments, lumbar spine dislocations; two of these remain paraplegic. Four sustained "Chance" fractures of lumbar spine; two of these were immobilized for 6 months in body casts and braces. One had "extensive intra-abdominal injury requiring laparotomy." All had seat belt bruises on their abdomen, facial contusions, the latter resulting from head strikes during hyperflexion over belt.

LeMire, J.R. et al (1967). Reports 2 cases. Case 1: 26-year woman at right front in rear end impact. Lap belt said to be "loose" and "high." Only sign of intra-abdominal injury was "ecchymosis and contusion of lower part of abdominal wall corresponding to site of seat belt." Five months post-crash, victim re-entered hospital. Exam found large hernia in right side of abdominal wall, containing colon and small intestine. (Cf. case described in Hurwitt and Silver.) Case 2: 24-year man in "head-on" crash. Lap belt "broke." On admission, general condition seemed good, but complained of pain, tenderness in lower abdomen. Observed for 7 hours, released. Ten hours later, returned to hospital with greatly increased abdominal pain, vomiting. Blood pressure was low, pulse elevated, weak. Abdomen rigid, with rebound tenderness. No bowel sounds. At surgery, 4-cm perforation found in proximal end of jejunum.

Ritchie, W.P. et al (1970). Reports four cases. Case 1: 35-year male driver involved in "head-on" collision "while passing at 50 mph." Car destroyed. Lap belt was in "proper position," but says that "buckle was arranged to ride across the lower part of the abdomen between the iliac crests." Lacerations to chin and knees. 12 hours after admission, abdominal distention, vomiting. 36 hours later, transferred in "moderate distress." Blood pressure 116/70, pulse 104. Abdomen "slightly distended, tense, diffusely tender." Rebound tenderness, most severe over right lower quadrant. No bowel sounds. No evidence of fractured lumbar vertebrae. At surgery, 1000 cc bloody fluid in peritoneal cavity. Terminal portion of ileum transected in 2 adjacent areas. Subjacent mesentery also interrupted, intervening tissue "clearly non-viable." 2 weeks in hospital. Case 2: Woman at right front in same crash. Severe back pain at admission. Fracture of 2d lumbar vertebra. 7 hours later, still severe pain, plus abdominal pain. Blood pressure 130/80, pulse 110, low fever. Transverse contusion over the lower part of abdominal wall corresponded to site of seat belt. Below contusion was palpable defect in tissues of anterior abdominal wall. Abdomen rigid, tender, with rebound tenderness over lower quadrants. No bowel sounds. At laparotomy, found circumferential serosal tear at midjejunal level, 1-cm punctate laceration of antemesenteric border of proximal protion of ileum, longitudinal serosal tear of hepatic flexure of colon. 2 months in hospital. Case 3: 11-year girl in same crash (seated rear). "Pale and agitated" at admission. Blood pressure 100/60, pulse 130 and "thready." Abdomen tense, moderately distended, extensive ecchymosis over lower quadrants. Diffuse rebound tenderness. No bowel sounds. Transverse fracture of body of 3d lumbar vertebra. At laparotomy, showed "circumferential transection of proximal protion of ileum. Serosal tear along antemesenteric border of ileum, just proximal to area of transection, rent in mesentery of ascending colon. 2 months hospital. Case 4: 7-year girl in same crash (rear seat). No signs of acute distress at admission. Blood pressure 104/60, pulse 100. Abdomen "soft and flat but not tender." Bowel sounds present. Tender contusions over anterior superior iliac spines bilaterally, no contusions on abdominal wall. Soft tissue swelling, tenderness, over lumbar spine were prominent. Fracture of 3d lumbar vertebra. Fracture of right transverse process. 5 weeks hospital.

Snyder, R.G. et al (1967). Reports 2 cases with correct lap belt use. Case 1: Right front female passenger in VW struck by oncoming car. Wearing a "snug" lap belt. Concussion, nose fracture, lacerations to cheek and left elbow. Numerous contusions and faintly visible marks from belt on lower abdomen and anterior superior iliac spines. 12 hours later, surgery found tear of jejunum about 8 inches below ligament of Treitz, which nearly severed the bowel. Case 2: 61-year woman in right front, "wearing a snug lap belt," in frontal crash at "about 30 mph." Compression fracture to body of first lumbar vertebra. Cites to "personal communication" with Nahum and Siegel, indicating in "their unpublished study of over 150 accidents in the L.A. area," more than 30 cases of seat belt injuries.

Tolins, S.H. (1964). Reports on man in right front wearing lap belt when car hit tree. Driver and three rear seat passengers unrestrained. They were all uninjured. Lap belted passenger suffered severe midabdominal wall contusion and perforation of upper jejunum. Admitted to hospital 28 hours post-injury, not operated on until 4th post-injury day.

Walpole, Bryan (1984). 45-year woman admitted to hospital after crash. "External signs of seat belt contusion" on abdomen. Swelling, generalized tenderness, marked guarding and rebound tenderness. Bowel sounds audible. "Extremely pale, very confused and gasping for air but responding to commands. Pulse 140, blood pressure 90/50, respiration 45/minute (shallow)." X-ray found left ruptured diaphragm, protrusion of abdominal contents into left chest. At emergency laparotomy, ruptured spleen removed, left 12th rib excised; diaphragmatic deficit repaired; several segments torn small bowel and mesentery removed; end-to-end anastomosis and relieving colostomy performed.

Williams, James S. and Kirkpatrick, John R. (1971). Discusses findings from 80 crash victims wearing lap belts. Intra-abdominal injuries in 42; 39 sustained intestinal or mesenteric injuries, or both. 51 had lumbar spine injuries: 32 fractures, 7 subluxations, 2 ruptured disks, 2 complete anterior dislocatoins. (6 spinal injuries were unknown). 7 patients had intra-abdominal injuries as well. 35 additional injuries due to belt: 22 to abdominal organs or other soft tissue, 4 fractured pelvis, 9 fractures of extremities or facial bones.

Williams, James S. et al (1966). Reports 4 cases, all involving correctly placed lap belts. Case 1: 42-year man in "severe" impact. Sustained perforation of mid-ileum. Case 2: 33-year woman in "severe" impact. Sustained transection of rectus muscle, blood in peritoneal cavity, mid-portion of omentum amputated from attachment to transverse colon (found "hanging by only one thin, vascular stalk"), multiple hematomas and lacerations along small bowel, contusion of right colon, serosal tear in right colon. 2 months in hospital. Case 3: 16-year girl in side impact into fire hydrant (side opposite victim). Transverse tear of duodenum around two-thirds of circumference. 3 months in hospital. Case 4: 20-year man in "severe" impact. 6-cm tear in mesentery of mid-ileum, 6-cm tear in mesosigmoid, contused sigmoid with subserosal hemorrhage, sigmoid questionably viable, blood in peritoneal cavity. 3-1/2 weeks in hospital.

APPENDIX D

GLOSSARY

This glossary briefly defines certain terms, as they have been used in this study and its appendices, that may be unfamiliar to the reader. Many of them refer to highly complex objects or processes; the definitions here are not intended to be exhaustive discussions of all aspects or nuances of these terms. Some of the definitions are based on Dorland's Illustrated Medical Dictionary (W.B. Saunders Co., 1981; 26th ed.); others are based on Johannessen and Vos, The Changing Shape of Seat Belt Systems (SAE 820796) and on Moffatt et al., Diagnosis of Seat Belt Usage in Accidents (SAE 840396).

For a fuller understanding of the anatomical parts referred to in the case summaries, consult the anatomical drawings reproduced from Dorland's at Appendix D.

ABDOMINAL FASCIA. Fibrous tissue forming part of the inner investing layer of the abdominal wall.

ANTERIOR. Situated in front of or in the forward part of an organ, toward the head end of the body.

AUTOMATIC LOCKING RETRACTOR (ALR). A retractor (see definition, below) that allows belt webbing to be withdrawn and then rewound, but will not permit a second withdrawal until the webbing is almost completely rewound. ALR's are most commonly seen in lap/shoulder belts with two retractors and in rear seat lap belts. The user pulls the lap belt out to a length greater than required, then latches it. The ALR rewinds the slack and then locks securely. These began appearing in American cars around Model Year 1968.

AVULSION. The tearing away of a part of a body structure.

BRAIN STEM. The stemlike portion of the brain connecting it with the spinal cord.

CERVICAL. Pertaining to the neck.

COMMINUTED. Broken or crushed into small pieces, as a comminuted fracture.

COMPRESSION FRACTURE. A fracture produced by compression (for example, a fracture of vertebrae)

CONTINUOUS LOOP. The most common type of lap/shoulder belt system in U.S. passenger cars today. One end of the lap belt is fixed to the vehicle, near the door sill, without a retractor; a continuous webbing extends across the occupant's lap, through a latch plate (either cinching or free-sliding), then up across the shoulder to a guide assembly or to an ELR. The lap belt length (snugness) must be manually adjusted by pulling webbing through the latchplate. The retractor is supposed to adjust the snugness of the shoulder belt portion automatically (perhaps affected by operation of any tension relief device in place).

CONTUSION. Bruise; injury of a part without a break in the skin.

DELTA V. Instantaneous rate of speed change at impact.

ECCHYMOSIS. A small hemorrhagic spot in the skin or mucous membrane, forming a nonelevated, rounded or irregular, blue or purple latch.

EDEMA. The presence of abnormally large amounts of fluid in the intercellular tissue spaces of the body; usually applied to demonstrable accumulation of excessive fluid in the subcutaneous tissues.

EMERGENCY LOCKING RETRACTOR. A retractor (see definition, below) that allows the webbing to be withdrawn and rewound freely, except when the retractor is caused to lock by vehicle acceleration, rapid webbing withdrawal, or some other non-manual system.

HEMOPERITONEUM. An accumulation of blood in the peritoneal cavity.

HEMOTHORAX. A collection of blood in the pleural cavity (thorax).

INFARCTION. An area of necrosis (dead tissue) in an organ caused by a cut-off in blood supply.

LACERATION. A torn, ragged, mangled wound.

LAPAROTOMY. Surgical opening of the abdomen.

LATCHPLATE (or "tongue"). The flat metal plate attached to one end of the belt webbing and extending inside the other part of the buckle. It usually has a hole through it or notches in its dies, which engage in the buckle when it is latched. (moffatt)

Le FORT I FRACTURE. A horizontal segmented fracture of the supporting bone of the upper teeth, in which the teeth are usually contained in the detached portion of the bone.

Le FORT II FRACTURE. Unilateral or bilateral fracture of the supporting bone of the upper teeth, in which the body of this bone is separated from the facial skeleton and the separated portion is pyramidal in shape; the fracture may extend through the body of the bone down the midline of the hard palate, through the floor of the orbit, and into the nasal cavity.

Le FORT III FRACTURE. A fracture in which the entire maxilla (supporting bone for the teeth) and one or more facial bones are completely separated from the brain case.

LIGAMENT. A band of fibrous tissue that connects bones or cartilages, to support and strengthen joints; a double layer of peritoneum extending from one visceral organ to another.

MANDIBLE. The bone of the lower jaw, the largest and strongest bone of the face. (See drawing of skeleton.)

MAXILLA GINGIVA. The gums of the upper teeth.

MESENTERY. A membranous fold attaching various organs to the body wall. When used alone, the term usually signifies the peritoneal fold attaching the small intestine to the dorsal body wall.

PARACENTESIS. A surgical puncturing of a body cavity to remove fluid (by aspiration).

PARIETAL (bone). One of the bones of the side of the head (see drawing of skeleton).

PERISTALSIS. The muscle movement by which the intestines move their contents.

PNEUMOTHORAX. An accumulation of air or gas in the pleural cavity.

POSTERIOR. Situated in back of, or in the back part of.

PULMONARY CONTUSION. Bruising of the lungs.

RETRACTOR. A device for storing part of the seat belt webbing by rolling it up.

RETROPERITONEUM HEMATOMA. A localized collection of (clotted) blood in the space behind the peritoneum (the membrane lining the abdominopelvic walls and covering the viscera).

SCAPULA. The shoulder blade (see drawing of skeleton).

SEPSIS. Infection.

SEROSA. Any serous membrane. (Deserosalization is a separation of serosa from the organ or part of the body to which it had been connected.)

SUBARACHNOID HEMORRHAGE. Intracranial hemorrhage into the subarachnoid space.

SUBDURAL HEMATOMA. Accumulation of blood in the subdural space (intracranial). In the severe acute form, both blood and cerebrospinal fluid enter the space through laceration of the brain and a tear in the arachnoid (a membrane within the brain), adding subdural compression to the direct injury to the brain. In the chronic form (a gradual process, occuring weeks after the injury), only blood effuses into the subdural space through rupture of the bridging veins, usually due to closed head injury.

SUBLUXATION. A partial dislocation.

SUBMARINING. A possible event during some crash decelerations, in which belted occupants slide downward and forward, resulting in the lap belt being repositioned above the iliac crests and over the abdominal area; it may also be possible for the same results to occur by a process involving the lap belt being pulled up past the iliac crests. Submarining is not a well-understood concept and some researchers have concluded it rarely if ever occurs.

TENSION RELIEF DEVICE. A device for reducing the tension in the shoulder belt portion of a lap/shoulder belt. The most common forms are the "comfort clip," a small clip positioned on the belt webbing to limit its ability to be taken up into the retractor, and the so-called "windowshade" device. In the latter device, by extracting webbing, pausing or rewinding slightly, then extracting slightly again, the locking mode of the retractor is triggered but with slack in the shoulder belt. The slack mode is supposed to be overridden automatically by some operation such as opening the occupant's door.

TRANSECTION. A division by cutting transversely, a cross-section cut.

TRAUMATIC THROMBOSIS. Formation of coagulated blood in a part following an injury.

TYMPANIC MEMBRANE. The membrane separating the middle from the external ear.

ULNAR STYLOID PROCESS. Part of the inner, larger bone of the forearm, on the side opposite that of the thumb (see drawing of skeleton).

VEHICLE SENSITIVE RETRACTOR. A type of emergency locking retractor (see definition above) that locks when the vehicle tilts or when it changes velocity sharply in any direction.

WEBBING SENSITIVE RETRACTOR. A type of emergency locking retractor (see definition above) that lockes when the webbing is suddenly withdrawn from the retractor, as in the early phase of a crash, but does not lock when the webbing is withdrawn slowly (normal use). (Webbing sensitive ELRs are required by European regulation; European retractors also include the vehicle sensitive feature as well.)

APPENDIX E

INJURY SEVERITY MEASUREMENT

A basic tool used in these investigations is the Abbreviated Injury Scale (AIS). 1/ This system for classifying the severity of physical injuries consists of six numbers, 1 through 6, plus a code to indicate unknown severity:

AIS	Severity Code
1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
6	Maximum injury, virtually unsurvivable

The "unknown" code used in the Safety Board's study is the numeral 7.

It is important to understand that the AIS code is specifically and only a measure of the severity of the injury. It is not a measure of the likelihood of death or any other outcome. Persons sustaining injuries at any AIS level may die from the injuries, depending on many factors such as the specific nature of the injury and the quality of treatment received. Death as an outcome is, of course, less likely at the lower levels and more likely at the higher levels.

Many persons injured in vehicle crashes sustain more than one injury. For comparisons, the most severe of these (Maximal AIS = MAIS) is often used, as in this study.

1/ As presented in the National Accident Sampling System (NASS) Injury Coding Manual (1983 Revision).

APPENDIX F

CRASH SEVERITY MEASUREMENT

The severity measure used in the Safety Board's cases is Delta V, considered by most crash researchers the best single measure of collision severity. Delta V as used in these investigations is the instantaneous rate of speed change undergone by a vehicle at impact. The Delta V estimations were generated primarily from measurements of damage sustained by the crash-involved vehicles. These measurements, of both the location and extent of structural deformation, along with the vehicles' weights, were entered into the CRASH 3 1/ computer program, through which they could be compared against the known results of crashes staged and documented over the past several years. This computer program analyzes such parameters as vehicle structural rigidity, force vectors with respect to vehicle center of mass, and the influence of individual vehicle weights. The result is a computer-generated estimate of the speed change acting on the crash vehicles at impact. While the program result is recognized as an estimate, the use of CRASH allows a uniformity of case study interpretation which could not be achieved by other commonly used investigative methods.

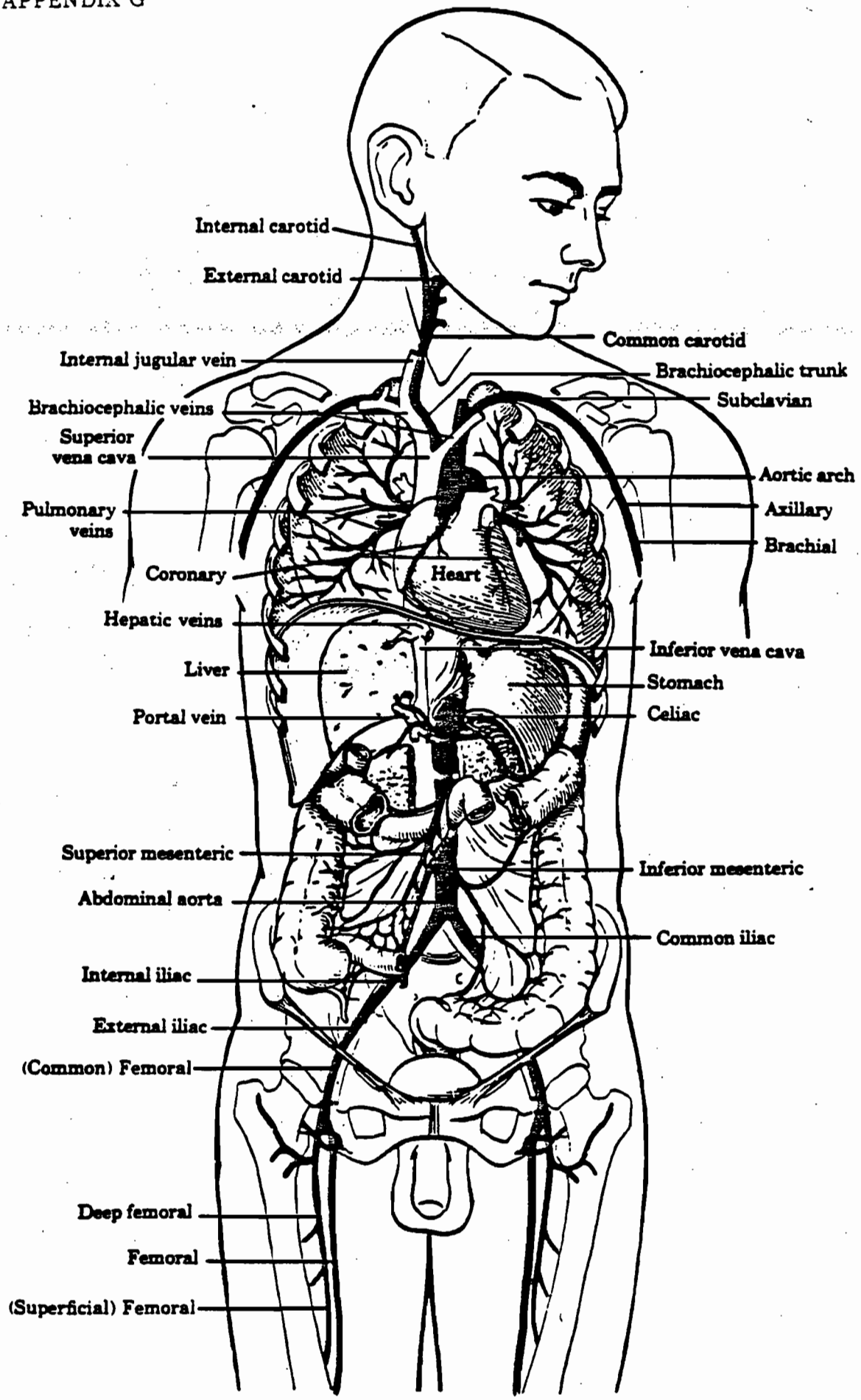
1/ CRASH stands for Calspan Reconstruction of Accident Speeds on the Highway. The program was developed with funding from the U.S. Department of Transportation as an "accident investigation aid aimed at achieving accuracy and uniformity in the interpretation of physical evidence from traffic accidents."

APPENDIX G

ANATOMICAL DRAWINGS

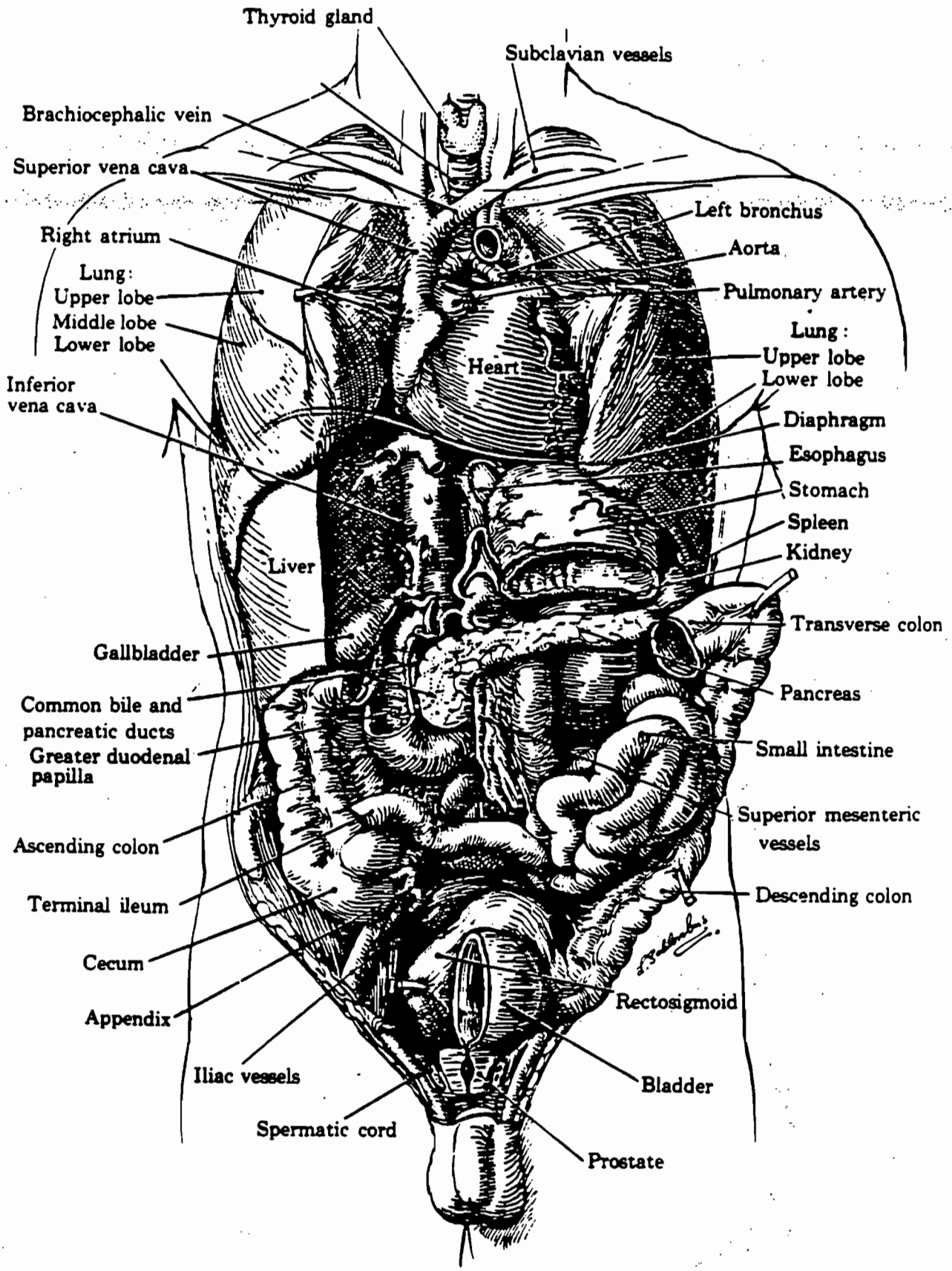
APPENDIX G

arteries



PRINCIPLE ARTERIES OF THE BODY AND PULMONARY VEINS

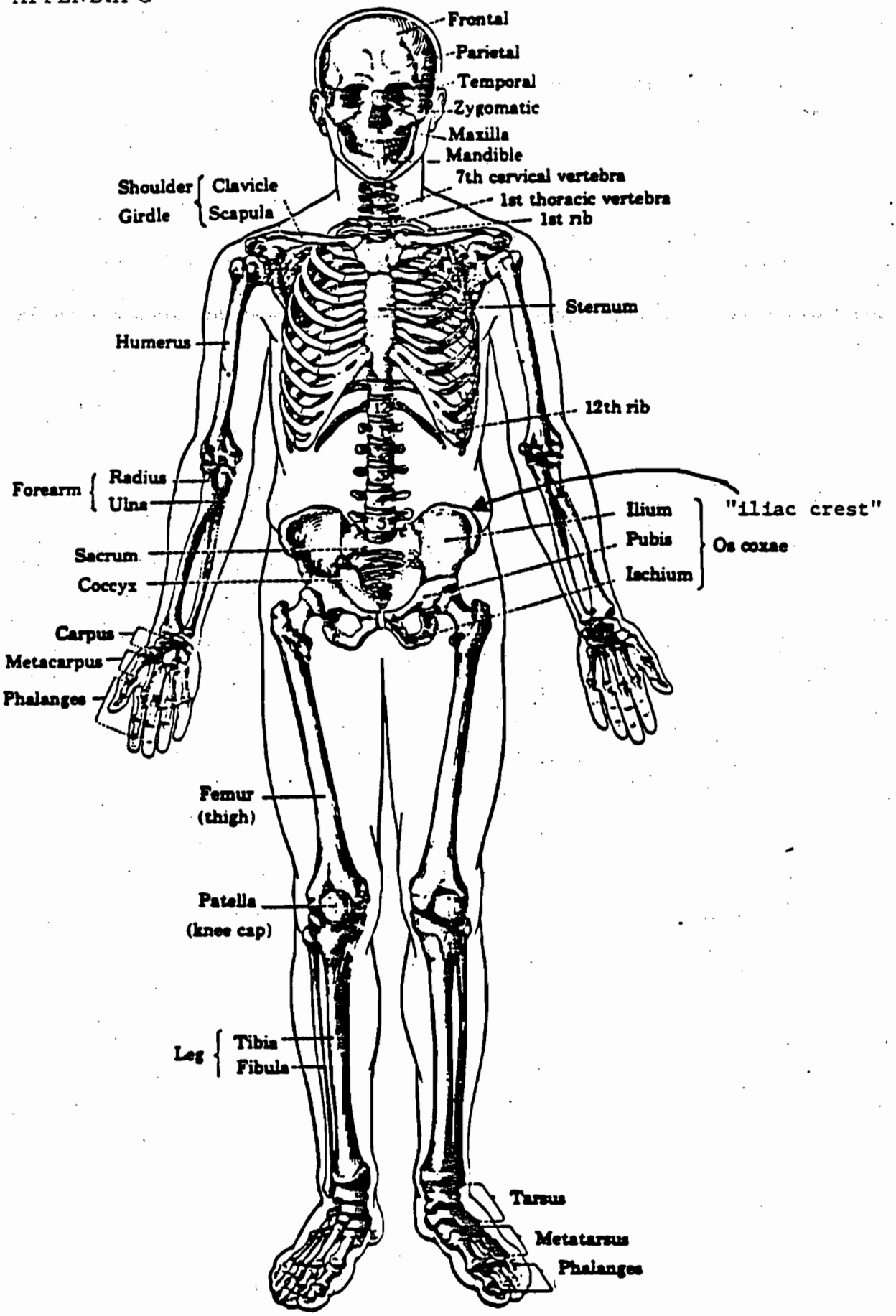
Plate LV **viscera**



THORACIC AND ABDOMINAL VISCERA

APPENDIX G

skeleton



ANTERIOR VIEW OF HUMAN SKELETON

(King and Showers)

APPENDIX H

PARTIAL CHRONOLOGY OF SEAT BELT RELATED EVENTS

This chronology of events related to the development and use of motor vehicle seat belts may provide some perspective for those unfamiliar with these topics. The Board was unable to locate a single, complete history of seat belts and their use; the following has been pieced together from a number of sources (14, 33, 52, 69, 71, 78, 82, 89, 110, 131, and correspondence of Thomas Turbell, Chief Biomechanics Researcher, Swedish Road and Traffic Research Institute, to Safety Board, October 11, 1985).

1930's

Several U.S. physicians equip their own cars with lap belts and begin urging manufacturers to provide them in all new cars

1953

Colorado State Medical Society publishes policy supporting installation of lap belts in all automotibles

1954

Sports Car Club of America requires competing drivers to wear lap belts

American Medical Association House of Delegates votes to support installation of lap belts in all automobiles

1955

California Vehicle Code is amended to require State approval of seat belts before their sale or use

National Safety Council, American College of Surgeons, International Association of Chiefs of Police vote to support installation of lap belts in all automobiles

Society of Automotive Engineers (SAE) appoints Motor Vehicle Seat Belt Committee

1956

Volvo markets 2-point cross-chest diagonal belt as accessory

Ford and Chrysler offer lap belts in front as option on some models

Ford begins 2-year ad campaign based on safety, focusing heavily on belts

1957

Volvo provides anchors for 2-point diagonal belts in front

Special Subcommittee on Traffic Safety, U.S. House of Representatives, opens hearings on effectiveness of seat belts in automobiles

1958

Volvo provides anchors for 2-point diagonal belts in rear

1959

Volvo introdues 3-point belt in front as standard, in Sweden

New York considers and rejects bill to require seat belts in new cars sold in State.

1960

New York again considers and again rejects seat belt bill

1961

SAE issues standard for U.S. seat belts (J4)

New York requires seat belt anchors at front outboard seat positions (effective January 1, 1962)

Wisconsin requires seat belts in front outboard seat positions

Standards Association of Australia issues standard for "safety belts and harness assemblies"

1962

Association for Aid to Crippled Children and Consumers Union sponsor landmark conference on "Passenger Car Design and Highway Safety" with occupant protection the sole theme

Six U.S. States require front outboard seat belt anchors

U.S. manufacturers provide seat belt anchors in front outboard as standard

1963

Volvo introduces 3-point belt in front as standard, in USA

Some U.S. manufacturers provide lap belts in front outboard positions (23 States have laws to require belts in front, most effective 1/64)

SAE issues revised standard (J4a)

U.S. Congress passes P.L. 88-201 to allow Commerce Department to issue mandatory standards for seat belts sold in interstate commerce

1964

About half the U.S. States require seat belt anchorages at front outboard

Most U.S. manufacturers provide lap belts at front outboard seat positions

Victoria and South Australia require seat belt anchorages at front outboard positions in new cars (either 2- or 3-point permitted)

1965

U.S. Commerce Dept. issues first seat belt standard (adopted SAE standard)

SAE issues revised standard (J4c)

All U.S. manufacturers providing lap belts in front outboard positions by this time

Some U.S. manufacturers provide automatic locking retractors (ALRs) in front seat belts

1966

Swedish regulations prohibit 2-point cross-chest diagonal belt at seats next to a door, and Y-type of 3-point belt altogether

U.S. Commerce Dept. issues revised seat belt standard (SAE J4c)

U.S. Congress passes P.L. 89-593, establishing National Highway Safety Bureau (now NHTSA)

Sports Car Club of America requires competing drivers to wear a shoulder harness as well as a lap belt (perhaps 1967, according to ref. 131)

1967

U.S. manufacturers provide lap belts at rear outboard positions (MY 1967)

NHSB issues initial Federal Motor Vehicle Safety Standards 208, 209, setting standards for lap and shoulder belts in front outboard positions, lap belts in all other positions (to take effect 1/1/68 and 3/67, respectively)

Volvo introduces 3-point belt in rear as standard, certain markets

Great Britain requires 3-points in front outboard positions

Australian standard for belt anchorages issued

South Australia requires seat belts (lap belts OK) at front outboard positions

1968

Volvo provides emergency locking retractors (ELRs) as standard in front, in Sweden

Great Britain requires retrofit of 3-point belts in front in MY 65 and newer cars

Many U.S. cars this MY provide ALRs.

1969

Sweden requires 3-point belts of approved type in front

Volvo provides 3-point belt in rear as standard, all markets

Mercedes-Benz adds 3-point belt in rear outboard seats as standard, all markets

Japan requires seat belts, front and rear

Australia requires 3-point belts, front outboard seats, all cars registered since 1965

1970

Sweden requires belts in rear (diagonal and static allowed; lap-only not approved)

Victoria, Australia requires 3-point belts, front and rear and mandates use, front and rear

1971

Volvo provides ELRs as standard in rear, all markets

NHTSA amends FMVSS 208 to require passive restraints in front, to be effective 1973

New South Wales requires use of seat belts

1972

Volvo introduces adjustable B-post anchor point (not standard) to permit better fitting of shoulder portion of front lap/shoulder belts

Last Australian state law requiring belt use, front and rear, goes into effect 1/1

New Zealand requires belt use, front and rear

W. Germany requires 3-point belts, front and rear

NHTSA requires anchorages for (detachable) shoulder straps for rear outboard (FMVSS 210)

VW displays 3-point belt system with webbing pre-tensioner (Transport 72, Washington, D.C.)

1973

Mercedes-Benz provides ELR on 3-point belts in large ("S" class) cars

1974

Mercedes-Benz provides ELR on 3-point belts in midsize (300 Series) cars

Sweden requires ELR on belts in front seats

NHTSA requires 3-point belts (i.e., non-detachable shoulder straps) in front outboard positions

U.S. cars provide "vehicle-sensitive" ELRs in front outboard shoulder belts (lap belt portion has ALR)

First production tension relief device on U.S. vehicle.

1975

Sweden requires 3-point, ELR belts in rear; mandates front use by persons 15 and older

1979

France mandates seat belts in rear: either 3 lap belts or 3-points at outboard positions and lap belt at center (most manufacturers choose latter option)

New Zealand requires 3-point belts, front and rear outboard positions

1980

Mercedes-Benz provides driver side airbag and knee bolster, and pre-tensioner on all 3-point belts

1981

NHTSA rescinds requirements for eventual installation of passive restraint systems

1983

New Brunswick and Ontario make belt use mandatory, front and rear (front seat use mandatory in Ontario since 1/76)

Saab introduces 3-point in rear in all models sold in U.S. (had provided "for years" in Scandinavia and Europe)

1984

Austria makes belt use mandatory in rear for cars with vehicle approval after 1/84 (front seat use mandatory since 7/76)

W. Germany makes rear seat belt use mandatory in cars manufactured since 5/79 (mandatory use in front since 1/76)

Seven of Canada's 10 provinces by this time require occupants of moving vehicles to use whatever seat belt system is available to them

1985

Nova Scotia makes belt use mandatory, front and rear

Norway makes rear seat belt use mandatory in vehicles registered after 1/84 (front seat use mandatory since 9/75)

New York makes belt use mandatory, front and rear (in rear for persons 10 years or older)

Mercedes-Benz introduces driver side air bag with knee bolster (in addition to pre-tensioned 3-point belts) in U.S. market

TABLES: RESTRAINT vs. INJURY vs. CRASH SEVERITY

RESTRAINT USE	DELTA V							
	0 - 15 MPH		16 - 25 MPH		26 - 35 MPH		36 - 45 MPH	
	AIS 1 - 2	AIS 3 - 6	AIS 1 - 2	AIS 3 - 6	AIS 1 - 2	AIS 3 - 6	AIS 1 - 2	AIS 3 - 6
NO RESTRAINT (57)	1		8	1	11	6	17	9
	FATALITIES RESULTING					1		3
	UNINJURED	4						
LAP BELT (50)	6		9	5	5	17	1	6
	FATALITIES RESULTING			4		6		3
	UNINJURED	1						
LAP/SHOULDER BELT (32)	5		7	1	8	6	2	1
	FATALITIES RESULTING					1		
	UNINJURED			2				

RESTRAINT vs. INJURY vs. CRASH SEVERITY (in 5 mph increments, with AIS distribution)

USAGE	INJURY LEVEL	DELTA V					
		0-20 MPH	21-25 MPH	26-30 MPH	31-35 MPH	36-40 MPH	41-45 MPH
UNRESTRAINED (57)	No. of AIS 1-2	1	13	4	2	15	2
	No. of AIS 3-6		2 AIS 3, 4	1 AIS 3	4 AIS 3, 3, 3, 5	5 AIS 3, 3, 3, 3, 3	4 AIS 3, 5, 6, 6,
	No. of FATAL				1 AIS 5		3 AIS 5, 6, 6
	No. of NONE	4					
LAP BELT (50)	No. of AIS 1-2	12	3	4	1	1	
	No. of AIS 3-6		5 AIS 3,5, 6,5,4	9 AIS 3,3,3, 4,4,5,5,5,5	8 AIS 3,5,5, 3,5,5,3,4	6 AIS 4,4,5 5,5,6	
	No. of FATAL		4 AIS 2, 6, 5, 5	2 AIS 5, 5	4 AIS 5, 5, 3, 4	3 AIS 5, 5, 6	
	No. of NONE	1					
LAP/SHOULDER (32)	No. of AIS 1-2	8	4	4	6		
	No. of AIS 3-6		1 AIS 3		5 AIS 4,3,4 4,3	1 AIS 4	
	No. of FATAL						
	No. of NONE		2				

APPENDIX J

TABLES: CASE INFORMATION, FATALLY INJURED LAP BELTED PERSONS

Delta V	Degrees PDOF	Veh.Wt.	Age	Sex	Use	Injury/Severity	Seat
37 mph	-10 to +10	2893 lb	13	M	P	AIS 5 - Fatal	R
37 mph	-10 to +10	2893 lb	13	M	P	AIS 5 - Fatal	R
23 mph	> -30	3690 lb	56	F	P	AIS 2 - Fatal*	R
22 mph	-10 to +10	2261 lb	5	F	P	AIS 6 - Fatal	R
26 mph	-10 to +10	3940 lb	16	M	I	AIS 5 - Fatal	R
32 mph	-10 to +10	2715 lb	4	M	P	AIS 5 - Fatal	R
22 mph	> +30	4250 lb	82	F	P	AIS 5 - Fatal	F
40 mph	-10 to +10	4720 lb	37	F	P	AIS 6 - Fatal	F
28 mph	-10 to +10	4935 lb	6	F	P	AIS 5 - Fatal	R
33 mph	-10 to +10	2824 lb	14	M	P	AIS 5 - Fatal	R
31 mph	-10 to +30	3488 lb	64	F	P	AIS 3 - Fatal*	R
25 mph	> -30	2968 lb	62	M	P	AIS 5 - Fatal	R
33 mph	-10 to -30	2330 lb	6	F	I	AIS 4 - Fatal	R

*Highest level of injury described by available records

Definitions of codes used:

P = Proper use of lap belt

I = Improper use of lap belt

N = No restraint used

PDOF = Principal direction of force

R = Rear seat

F = Front seat

SERIOUSLY TO FATALLY INJURED LAP BELT USERS: SELECTED CRASH DATA, BY DELTA V

DELTA V	AGE								SEX		USE			FORCE				VEH. SIZE				
	0 - 5 YRS	6 - 10 YRS	11 - 15 YRS	16 - 20 YRS	21 - 30 YRS	31 - 40 YRS	41 - 50 YRS	OVER 50 YRS	FEMALE	MALE	PROPER	IMPROPER	UNDETERMINED	- 10° to + 10°	+ 10° to + 30°	- 10° to - 30°	OTHER	UNDER 3000 lbs	OVER 3000 lbs	VAN/TRUCK	TOTALS	Codes
											P	I	U	A	B	C	D	1	2	3		
15 - 20 MPH																						FATAL INJURIES ONLY
21 - 25 MPH	1							3	3	1	4			1			3	1	3		4	
26 - 30 MPH		1		1					1	1	1	1		2					1	1	2	
31 - 35 MPH	1	1	1					1	2	2	3	1		2	1	1		3	1		4	
36 - 40 MPH			2			1				3	3			3				2		1	3	
OVER 40 MPH																						
TOTALS	2	2	3	1		1		4	6	7	11	2		8	1	1	3	6	5	2	13	
15 - 20 MPH																						FATAL, AIS 3, AIS 4, AIS 5, AIS 6, INJURIES COMBINED
21 - 25 MPH	1					2		3	5	1	6			1		2	3	2	4		6	
26 - 30 MPH	1	6	1	1					2	7	8	1		9				1	2	6	9	
31 - 35 MPH	2	1	2		1			2	4	4	2	1		5	2	1		6	2		8	
36 - 40 MPH			2	2	1	1			1	5	6			6				2		4	6	
OVER 40 MPH																						
TOTALS	4	7	5	3	2	3		5	12	18	28	2		22	2	3	3	12	8	10	29	