THE JOURNAL OF TRAUMA
Vol. 11, No. 3

Printed in U.S.A.

THE NATURE OF SEAT BELT INJURIES

JAMES S. WILLIAMS, M.D., AND JOHN R. KIRKPATRICK, M.D.*

From the Department of Surgery, University of Rochester School of Medicine and Dentistry, Rochester, New York

The use of the safety belt by automobile occupants was suggested by Straith in the late 1930's (44). In 1942, DeHaven (12) and later Stapp in 1951 (42) proved conclusively by their studies that restraining devices were invaluable in increasing "*g*" tolerance of the human to abrupt deceleration. Over the next decade, more and more automotive seat belts were installed and, when used, were found to be effective (9, 14, 37). Controlled accident studies in the late 1950's comparing nonbelt-users with belt-users demonstrated a 60% decrease in injury (7, 30) and a 35% reduction in major or fatal trauma by the use of a restraining device (48).

The first dash of cold water on this panacea for road survival was thrown by Kulowski and Rost (28) in 1956 when they reported a case in which the injury sustained was attributed to a safety belt. Since then, numerous cases have appeared in the literature. These reported cases and others obtained by personal correspondence or experience form the basis for a description of the nature of seat belt injuries.

CLINICAL MATERIAL

The data from those previously reported patients who received injury while wearing a restraining device were carefully reviewed and analyzed. Twelve cases not previously reported are summarized in Table I. The nature of the injuries associated with a lap belt are different from those produced by the two-point or diagonal belt and the three-point, and therefore these will be considered separately.

Presented in part at the Twenty-eighth Annual Session of the American Association for the Surgery of Trauma, Montreal, Quebec, October 18–20, 1968.

* Now at the University of Kansas Medical Center, Kansas City, Kansas 66103.

Address for Reprints: James S. Williams, M.D., Department of Surgery, The University of Rochester, School of Medicine and Dentistry, 260 Crittenden Boulevard, Rochester, New York 14620.

RESULTS

LAP BELT

A total of 87 accident victims have been collected who were wearing a lap-type safety belt (1, 3, 5, 12, 13, 17, 19, 21–25, 27–29, 31–34, 39, 43, 45, 46, 50, 52). Eighty occurred in auto accidents and seven in airplane crashes (17, 39, and J. H. Morton, personal communication). They ranged in age from 9 to 72 years, with two-thirds under age 35. Males predominated in a ratio of two to one.

The victim was the driver in 28 instances, in the right front seat in 40, left rear in three, right rear in three, and rear in four. The position of the victim was unknown in nine cases. The collision was front end in 70 accidents, broadside in 12, rear in two, and unknown in three. Four of the seven airplane crash victims were seated sideways, and are considered in the broadside group. The speed at impact ranged from 15 to 80 mph, but in the majority of cases was in excess of 30 mph.

Intra-abdominal injuries occurred in 42 of the accident victims. Thirty-nine sustained intestinal or mesenteric injuries, or both (Table II). Contusion of the intestine was characterized by subserosal ecchymosis. Seromuscular tears were longitudinal

TABLE I

Lap Belt Injuries Not Previously Reported

Author	Situation of Accident	Symptoms and Physical Findings	Timing of Operation	Pathology	Course
Morton	33-year-old man, airplane crash, 90 mph	Scalp laceration, shock; peritoneal tap positive; no bowel sounds	2 hr	5-inch tear in mesentery of ileum, 3,000 ml blood	Partial wound disruption 10th postoperative day related to pneumonia, discharged 23rd postoperative day
Quinn	Unknown	Shock	Early 12 hr	Transverse tear in jejunal mesentery plus seromuscular tear; hemorrhage, lacerated spleen; adhesions from previous operation	Presumed recovered
Williams	75-year-old woman driver, car struck on right side, auto traveling 50 mph	Localized tenderness left lower abdominal wall with bruise	None	Developed 3" diameter intramuscular hematoma medial and superior to iliac crest	Hematoma resolved in 2 weeks
Boger	70-year-old woman front passenger, right front into concrete abutment	Pain, tenderness, ecchymosis right lower quadrant and iliac crest	None	Comminuted fx right iliac wing and 4" hematoma of lower abdominal wall	Recovered in 6 weeks
Huene	19-year-old male driver, head-on into a boulder at 25 mph	Compression fxlx, fx both bone of right forearm, contusion of lower abdominal wall; peritoneal tap twice negative; peritoneal catheter positive; X-ray free air	36 hr	Perforation of jejunum 2' from ligament of Treitz	Recovered
Huene	18-year-old male passenger, brother of above patient	Lower abdominal bruise and tenderness, peritoneal tap negative twice, peritoneal catheter positive	36 hr	Perforation of jejunum 2' from ligament of Treitz	Recovered
Wiles	60-year-old man in right front seat, car struck rear at red light; had been drinking beer	Lower abdominal tenderness and spasm; prostate high on rectal; urethrogram "poor definition"	Early 12 hr	Ruptured membranous urethra	Recovered
	21-year-old male passenger, speed and direction of impact unknown	Generalized abdominal pain and tenderness, X-rays negative	6 hr	Perforation distal to ligament of Treitz	Recovered
	32-year-old obese woman passenger; speed and direction of impact unknown	Severe abrasion over right iliac crest	2 months	Progressed to full-thickness skin necrosis, the width of the belt for 2" requiring grafting	Recovered
Fisher	45-year-old woman in right front seat in head-on collision, speed ?	"Acute abdomen"	Early 12 hr	Perforation of jejunum	Recovered
	48-year-old man in head-on collision, speed ?	Concussion and "musculoskeletal" injuries, peritoneal tap free blood	Early 12 hr	Avulsion of sigmoid mesentery and seromuscular tear of sigmoid	Recovered
Zeplowitz	Middle-aged woman in right front seat, head-on collision	Lower abdominal tenderness and contusion, hypotension	Early 12 hr	15-cm tear of ileal mesentery	Recovered
States	70-year-old male driver, head-on right front of car at 35 mph	Tenderness over right iliac crest	None	Right iliac wing fractured	Recovered
Redman	48-year-old male driver, head-on at 50 mph	Contusion of lower abdomen, facial lacerations and fx of L3	None	Transverse fx of L3	Recovered
Hoyt	22-year-old male driver, head-on 50 mph	Abdominal tenderness, fx 2 ribs on right, shock	Early 12 hr	Transverse tear in mesentery of ileum 3 liters of blood	Recovered

TABLE II

p Belt: Intestinal and Mesenteric Injuries

Injury	Small Intestine	Large Intestine	
ntusion	3	4	
omuscular tear	11	4	
foration	26	4	
enteric tear	23	7	
Subtotal	63	19	
TOTAL			82

ith a rent in the serosa and external muscle layer of the small intestine, while those occurring in the large intestine extended to mucosa. The jejunum and ileum were equally involved. Seromuscular tears occurred in the sigmoid colon twice, ascending colon once, and transverse colon once. Perforation of the intestine was formed on the antimesenteric side of the bowel in all but three instances, and in one case transection of the jejunum was encountered. Jejunal perforation was found in 15 instances and ileal perforations in eight instances. Three duodenal perforations occurred in the third portion on the antimesenteric side. One patient was a right front seat passenger involved in a left lateral impact accident, and two were drivers in head-on collisions. Cecal perforation was noted in two patients, one also suffering a sigmoid perforation. Mesenteric tears occurred three times more frequently in the small bowel than in the large. The jejunal mesentery was torn perpendicular to the bowel in three instances and transverse in four. Perpendicular tears were recorded 10 times in the ileal mesentery, and transverse tears were recorded in five. The sigmoid mesentery was torn in six patients, with transverse and perpendicular tears occurring with equal frequency. A transverse tear at the base of the transverse mesocolon occurred in one case. The mesentery lacerations resulted in blood loss from 1 to 3 liters in half the patients.

The next most common injury associated with lap belt use was to the lumbar spine (Table III). Thirty-two fractures, seven subluxations, two ruptured disks, and two complete anterior dislocations of the spine were recorded. In six instances the exact nature was unknown. Seven patients had intra-abdominal injuries as well. Dorsal and cervical spine injuries were not recorded.

Additional injuries attributed to lap belt numbered 35 (Table IV). Eight abdominal wall injuries included transection of the rectus muscle (bilateral in two cases), hematoma in three, full-thickness skin necrosis, and delayed hernia. Fracture of the iliac wing occurred in four patients, and was most likely related to door collapse

TABLE III

Lap Belt: Lumbar Spine Injuries

Compression fracture	9
Subluxation	7
Fracture articular process	7
Fracture lamina and pedicles	2
Complete anterior subluxation	2
Horizontal (Chance Fx L_1 or L_2) (10)	10
Transverse process fracture	2
Rotational fracture	2
Disk rupture	2
Posterior ligamentous tear	2
Unknown	6
TOTAL	51

TABLE IV

Lap Belt Accidents: Additional Injuries

Soft tissue	
Abdominal wall	8
Spleen	4
Omentum	2
Pancreas	2
Uterus	2
Urethra	1
Iliac artery	1
Rupture diaphragm	1
Liver	1
Fractures	
Extremities	6
Pelvis	4
Facial	3
TOTAL	35

into the occupant compartment in one instance. Splenic rupture occurred in three patients, and in one was associated with fractured ribs. The omentum was amputated from its attachment to the transverse colon in two cases. Two patients with pancreatitis had duodenal rupture as well. Only one case of uterine rupture has been reported. The urethral injury is the only one of its kind known. Iliac artery injury with thrombosis occurred once.

Additional injuries not directly related to the lap belt were recorded in 36 accident victims' reports. Facial fractures were sustained in seven cases, extremity fractures in 12, and rib fractures in two. Contusion, abrasion, concussion, facial and other lacerations were among the other injuries. In all instances these injuries were thought to result from equipment failure, faulty design, or compartment collapse. Improper placement of the belt could not be ascertained, but may have contributed to these additional injuries.

Operative treatment was indicated in 37 patients who sustained lap belt injuries. When surgical intervention was undertaken within 12 hr of injury, morbidity was minimal and mortality was low (Table V). However, delay of more than 12 hr was accompanied by considerable morbidity and mortality (Table V). Deaths were the result of peritonitis with overwhelming sepsis, and were related to delay in diagnosis, the abdominal findings being masked by associated injury. The only other mortality occurred in a man who sustained multiple mesenteric lacerations in an airplane accident and bled to death before resuscitative measures could be undertaken.

TABLE V

Lap Belt Accidents: Time of Operation

	Number of Cases	Morbidity	Mortality
Less than 12 hr	23	2	1
More than 12 hr	14	5	2

The diagnosis of intra-abdominal injury was made on the basis of physical findings or clinical course. 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% 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 of little diagnostic help. An elevated amylase, indicative of traumatic pancreatitis or ruptured duodenum, was not recorded. Abdominal roentgenograms would have been helpful in diagnosing ruptured gravid uterus early, but did not aid the diagnosis of intestinal perforation until late. Early peritoneal paracentesis done in 13 cases was positive in only six and was falsely negative in seven. Eleven patients were admitted in shock, and all had intraperitoneal blood loss up to 3 liters.

TWO-POINT DIAGONAL AND SHOULDER RESTRAINTS

We collected the records of 24 accident victims who were injured wearing shoulder restraints alone (2, 4, 16, 19, 35, 49). Twenty-one were using the two-point cross shoulder diagonal belt, and three a shoulder harness. The ages ranged from 17 to 66 years, with men predominating three to two. The speed at impact was greater than 40 mph in all but two accidents. The victim was the driver in 13 accidents and passenger in 11. Since diagonal belts are seldom installed in the back seat, no such injuries are recorded. Collision was front end in 18 instances, side in five, and rear in one.

Injuries sustained from a shoulder restraint were predominantly skeletal (Table VI). Rib fractures were noted in nine instances. Four were drivers, four were passengers, and one was unknown. Both upper and lower, and right and left ribs were fractured in driver and passenger. Cervical spine fractures occurred in four cases, and were fatal in three. Two were associated with

decapitation. The only vertebral injuries were compression fractures of the thoracic and lumbar spine noted in three victims; it was the only injury in two.

Skin and soft tissue injuries consisted of five contusions, hematomas, and abrasions; two ligamentous injuries to the cervical spine; one torn diaphragm; and fat necrosis underlying the extent of the belt contact in one victim.

Organs injured included laryngeal contusion with hematoma or fracture; liver laceration; liver and spleen laceration; ruptured kidney; lacerated spleen; avulsion of hepatic veins; and avulsion of both renal artery and vein. In five cases intra-abdominal visceral injury was accompanied by fractured ribs.

Additional trauma occurring in those injured from shoulder restraints included two upper extremity fractures, six lower extremity fractures, two facial fractures, four major lacerations and contusions, one severe head injury, and three concussions. In only five cases did the belt prevent the victim from colliding with the interior of the vehicle.

In 13 of the 24 victims injured, equipment failure, faulty design, or collapse of passenger compartment was responsible for the belt producing the injury or for the production of associated injuries. Belt failure occurred late in one case and did not contribute to injury. Improper placement of the belt under the arm contributed to injury in one case.

Eight deaths occurred in the shoulder restraint group. Fracture of the cervical spine resulted in three fatalities. It occurred when the door flew open and the victim was ejected, left hanging by his belt. Four persons bled to death from intraperitoneal blood loss, two from fractured liver or spleen, and two from major vessel tears. The final death occurred as a result of pulmonary insufficiency secondary to fat emboli from an area of fat necrosis along the entire course of the belt as well as long bone and rib fractures. In five of these cases, lateral impact was recorded. The one woman who had her belt under her arms in the right front seat sustained fractured ribs, lacerated diaphragm, ruptured liver, contused right kidney, and fractured left leg, and died.

TABLE VI

Shoulder Restraint Injuries

Fractures	
Ribs	9
Cervical spine	4
Thoracic spine	3
Lumbar spine	1
Sternum	3
Skin and soft tissue	
Contusion, hematoma, and abrasion	5
Ligamentous injury, cervical spine	2
Fat necrosis	1
Diaphragmatic tear	1
Organs	
Larynx	2
Liver	2
Liver and spleen	1
Kidney	1
Major vessel	2
Spleen	1

Cervical and upper rib cage injury occurred in those victims who slid under the belt on impact, while lower rib cage and abdominal visceral injury occurred when the individual was thrown over the belt.

THREE-POINT SHOULDER RESTRAINT

A total of 63 individuals have been injured as a result of wearing a three-point cross shoulder-lap belt restraint (6, 15, 18). In six instances the victim was the driver, and in 27 a passenger seated in front. The ages ranged from 18 to 60. The majority of injuries occurred at speeds in excess of 30 mph.

The most common injury was single rib fracture, recorded in 20 cases (Table VII). Multiple rib fractures were sustained by the driver in six separate accidents, and by passengers in two. Sternal fracture was sustained by the driver three times and a passenger once. Five fractures of the clav-

TABLE VII

Three-point Belt Injuries

Fractures	
Rib, single	20
Rib, multiple	8
Sternum	4
Clavicle	5
Abdomen	
Organs unknown	3
Jejunum, perforation	1
Duodenum, perforation	3
Contusions and abrasions	
Chest	11
Lap area	5
Shoulder	4
Neck	4
Back	2
Other	1

icle were noted. Slight superficial wound of the cheek due to the belt webbing was noted twice. The remaining injuries included contusion from the belt and back strain. Insufficient information is available to determine the nature of the intra-abdominal injuries in three cases. However, rupture of the duodenum was reported in two instances and perforation of the jejunum in one case.

Additional injuries have been recorded which were not felt to be related to the belt. Forty-two of the facial lacerations were severe. Extensive trauma to the upper extremity occurred in eight instances and to the lower extremity in two. Only three deaths occurred, and in all the speed at impact was in excess of 60 mph. Although insufficient data are available, these additional injuries were most likely due to compartment collapse, faulty design, equipment failure, or improper placement of the restraining device.

DISCUSSION

The automotive restraining devices have three beneficial effects during a collision. They prevent ejection (47, 53), allow the occupant to decelerate with the car during the first few milliseconds when energy-absorbing plastic deformation of the car occurs (38), and to a great extent prevent the second collision of the victim with the interior of the car. The effect of the safety belt in preventing fatality has been estimated to be 40% (26). Although the seat belts prevent serious injury and death, they may expose the wearer to additional injury.

All three major types of belts are capable of producing injury. Each has its own characteristic pattern of trauma.

The lap belt, either because it is worn above the iliac crests or migrates there during the accident, produces injury to the abdominal wall or the peritoneal contents. Fifty-eight percent of those injured with this restraint suffered intra-abdominal injury, and of those 95% sustained intestinal and mesenteric trauma. One theory proposes that the intestinal injuries result from compression of the bowel against the vertebral column (51). Although this may be the cause of some injuries, it is not the cause of all, since the colon has perforated as well as the small bowel. It has been postulated that during the deceleration the loading of the intestine is so rapid that it does not have time to undergo elastic deformation, behaves like a rigid plastic tube, and actually fractures (52). This is doubtful, however, since the average impact speed was 35 mph and front end in the majority of the cases. Forces acting through the belt did not begin to act on the belt until 40 milliseconds had passed from time of impact. Over the next 100 milliseconds, forces increased to a maximum of 5,500 lb., were reduced to an estimated 20 *g*, and were questionably able to act fast enough to exceed the elastic properties of the intestine. As the victim proceeds forward, the belt is loaded. Because of elastic properties it stretches from 3 to 6 inches. The belt recoil is minimal. However, this force is applied to the abdomen also. The duration of this force may be of sufficient duration to burst the intestine (Fig. 1) or tear the mesentery (Fig. 2). Furthermore, since the majority of perforations were antimesenteric, it is un-

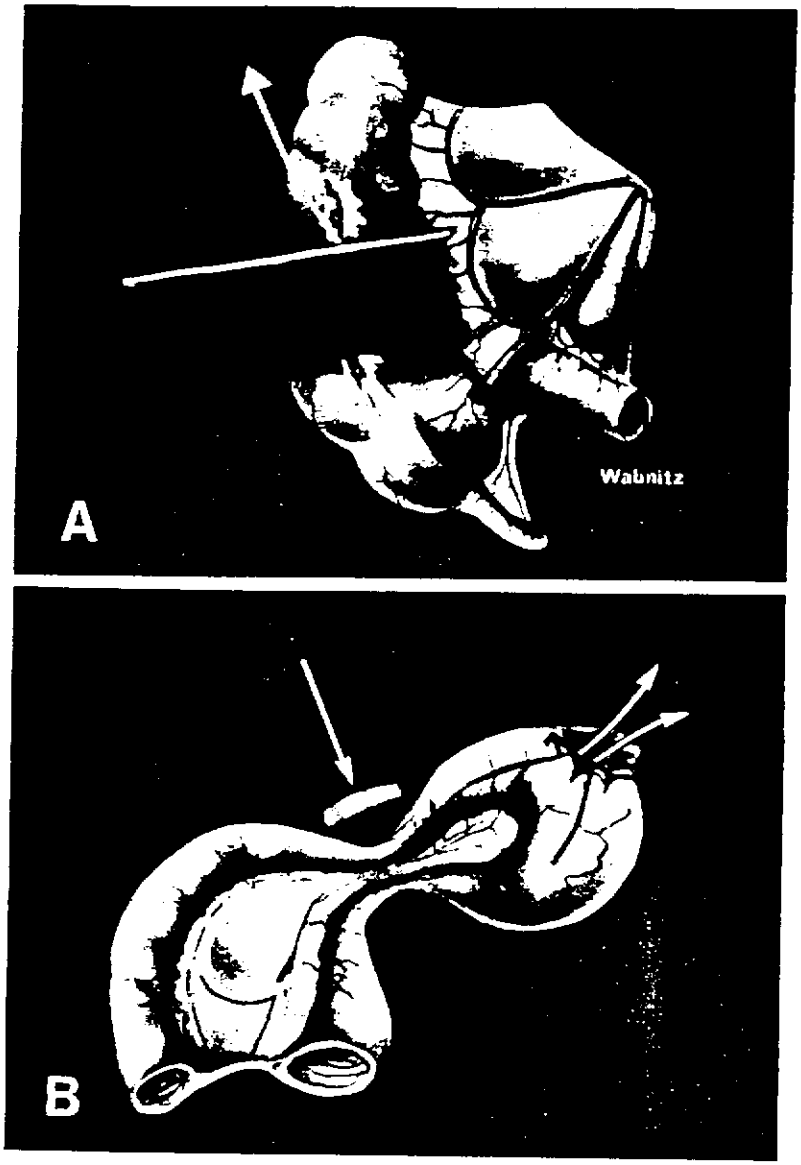

FIG. 1. It is postulated that (A) seromuscular tears occur from direct violence of the lap seat belt acting through the abdominal wall and (B) bursting is the result of a functional closed loop obstruction increasing intraluminal pressure.

likely that they were produced by fracture. Further investigation will be necessary completely to elucidate the exact role of the seat belt in producing fracture, or intestinal and mesenteric injury.

The lap belt also exposes the user to injury to the lumbar spine. The driver is protected from severe flexion by the steering wheel, while the passengers may flex freely at the time of impact. These injuries occurred with front end collision, and rarely were seen with the other restraints. Unique to the lap belt is the bilateral transverse fracture of L2 or L3 described by Chance (10).

Additional visceral injuries due to the lap belt were due to direct violence, generally from an ill-placed belt. Although

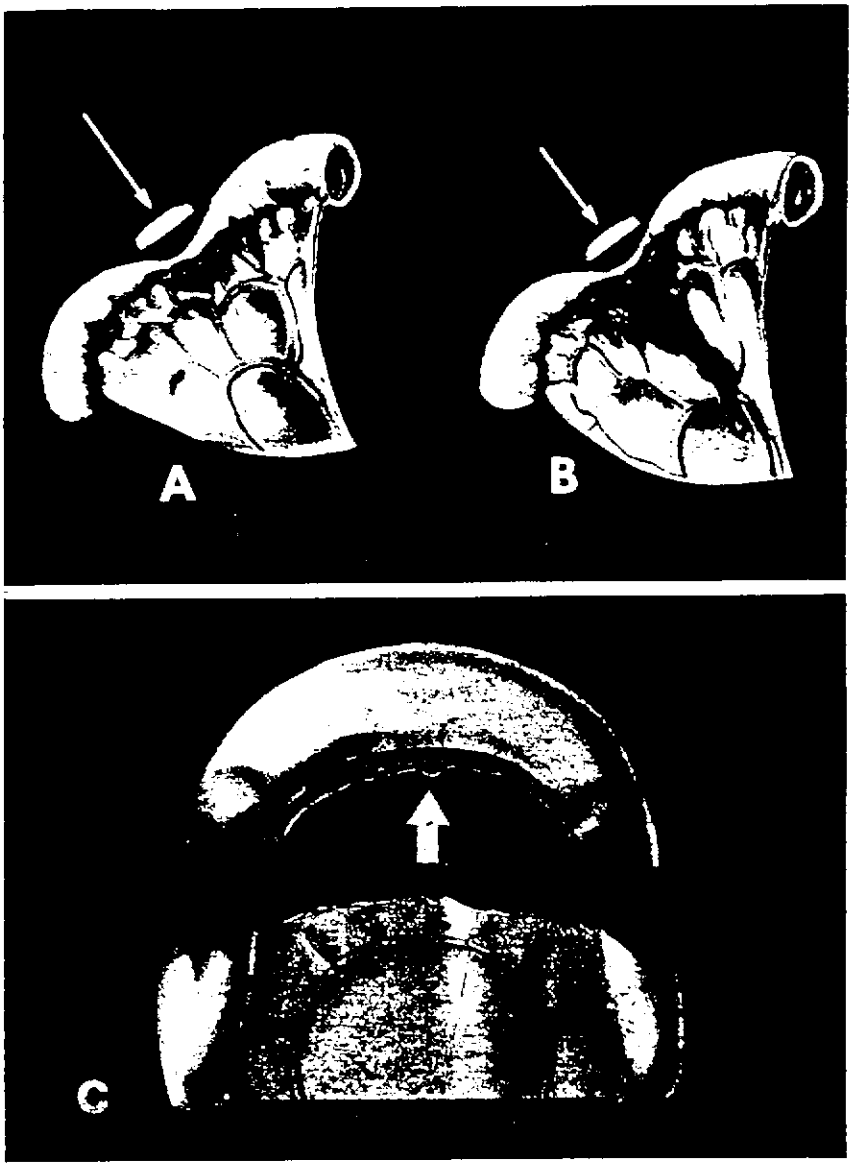

FIG. 2. Mesenteric injuries from the lap belt may result from direct violence producing a hematoma (A) or a perpendicular tear (B). Parallel mesenteric tears (C) may be caused by entrapment of the intestine along the mesenteric border.

several cases of pregnant uterine trauma (41) due to a safety belt have been reported, only two resulted in a ruptured (34) or avulsed uterus (39).

The two-point or diagonal belt causes predominantly skeletal injuries to the ribs, sternum, and spine. Although some pocketing occurs in the belt at the level of the neck, injury still was produced. Furthermore, when doors opened, the belt did not prevent submarining and ejection. Severe flexion over the belt, whether it is applied correctly or incorrectly, exposed the wearer to severe intra-abdominal injuries and a possible mortality rate of 33%.

The three-point belt has been the most

effective restraining device in attenuating occupant injury. No deaths have been reported in collisions up to 60 mph, as opposed to a control series where unrestrained occupants were subject to fatality throughout the impact speed spectrums. Chest injury was most common with this belt system, occurring in 2% to 5% of the injured. The three individuals who were killed suffered fatal head injuries at impact speeds in excess of 60 mph. These head injuries and the 1.4% additional injuries, not attributed directly to the lap or two-point belt, occurred in 30% and 54% of the victims respectively. With the three-point belt on, 1.5% of those injured had additional injury.

It can be seen that the combination of lap and shoulder restraint system gives the greatest protection against injury. This is not surprising, since it has been shown that at impact speeds of 30 mph the restrained passenger tends to decelerate with the decreasing passenger compartment velocity sooner than the unrestrained occupant. Furthermore, peak chest deceleration is reduced from 15 g to 9 g. Of more importance, this force is applied to the sturdy thorax (38).

The high incidence of associated injuries to the head and extremities deserves consideration. Attention must be directed to interior design modifications of the vehicle in order to prevent the restrained occupant from injury by striking the interior of the car. If this cannot be done, then energy-absorbing materials should be placed at the vulnerable contact points (38). An even more serious cause of associated injury is penetration of the passenger compartment. This has resulted in a mortality and morbidity rate that far exceeds non-penetrating accidents.

Since the extensive use of the lap-shoulder restraint system will be slowly adopted, and since more auto occupants are wearing lap belts, the physician must be alert to injury potential of this device 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. If the injury is diagnosed and treated early, survival is assured.

Far more deaths and morbidity result from lack of restraints than with them (2, 8, 9, 20, 26, 37, 47, 48, 53). The loss of man hours and dollars can be attenuated by intense public education and a plea for using safety restraints.

SUMMARY

1. This study investigates the nature of safety belt injuries based on an analysis of those cases which appear in the literature as well as some not previously reported. The injury pattern is characteristic for each type of restraint system.

2. Eighty-seven accident victims received injury from a lap-type belt. Intra-abdominal trauma was found in 42 cases, and involved the intestine or its mesentery in 39. Fifty-one injuries to the lumbar spine occurred, and in seven were associated with intra-abdominal injury as well. Thirty-six victims received additional injury not related to the belt. Four deaths occurred.

3. A two-point diagonal or shoulder restraint produced injury to 24 accident victims. Skeletal injury predominated, with nine instances of fractured ribs and four cases of fracture dislocation of the cervical spine. Visceral injury when noted was severe. Eight deaths occurred in this group. Thirteen received injury not related to the belt.

4. Sixty-three accident victims received injury from a three-point (shoulder-lap) belt. Fractures of the ribs, clavicle or sternum were the most common. Intra-abdominal injury was rare. Three deaths were recorded, all at speeds over 60 mph.

5. It is estimated that in the majority of accidents the victim would have been killed without a restraining device.

6. On the basis of this study, a combina-

tion shoulder and lap restraint system is most effective in preventing injury and mortality.

REFERENCES

1. Aiken DW: Intestinal perforation and facial fractures in an automobile accident: victim wearing a seat belt. *J Louisiana State Med Soc* 115:235–236, 1963
2. Backstrom CG: Traffic injuries in South Sweden, with special reference to medico-legal autopsies of car occupants and value of safety belts. *Acta Chir Scand* Suppl 308:1–104, 1963
3. Backwinkel KD: Injuries from seat belts. *JAMA* 205:305–308, 1968
4. Bergstrom J: Neck injury from a safety belt. *Svensk Läraretidning* 58:3100–3101, 1961
5. Blumenberg RM: The seat belt syndrome: sigmoid colon perforation. *Ann Surg* 165:637–639, 1967
6. Bohlin NI: A statistical analysis of 28,000 accident cases with emphasis on occupant restraint value. 11th Stapp Car Crash Conference. New York, Society of Automotive Engineers, Inc., 1967, p. 299–308
7. Braunstein PW: Medical aspects of automotive crash injury research. *JAMA* 163:249–255, 1957
8. Bruius U, Lindgren S: The effectiveness of safety belts: an analysis of 210 belt cases. *Nord Med* 66:1500–1503, 1961
9. Campbell HE: Role of the safety belt in nineteen auto crashes. *Bull Amer Coll Surg* 40:155–158, 1955
10. Chance GQ: Note on a type of flexion fracture of the spine. *Brit J Radiol* 21:452–453, 1948
11. Cocke WM Jr, Meyer KK: Splenic rupture due to improper placement of automotive safety belt. *JAMA* 183:693, 1963
12. DeHaven H: Mechanical analysis of survival in falls from heights of 50 to 150 feet. *War Med* 2:586–596, 1942
13. Doersch KB, Dozier WE: The seat belt syndrome: the seat belt sign, intestinal and mesenteric injuries. *Amer J Surg* 116:831–833, 1968
14. DuBois EF: Safety belts are not dangerous. *Brit Med J* 2:685–686, 1952
15. Ebbetts J: Seat belts and cervical spondylosis. *Practitioner* 188:802, 1962
16. Engberg A: Injuries caused by safety belts: a contribution to the discussion with reference to an unusual case. *Svensk Lakartidn* 58:884–886, 1961
17. Fish J, Wright RH: The seat belt syndrome—does it exist? *J Trauma* 5:746–750, 1965
18. Fisher P: Injury produced by seat belts: report of two cases. *J Occupat Med* 7:211–212, 1965
19. Fletcher BD, Brogdon BG: Seat-belt fractures of the spine and sternum. *JAMA* 200:177–178, 1967
20. Frazier RG: Effectiveness of seat belts in preventing motor vehicle injuries. *New Eng J Med* 264:1254–1256, 1961
21. Garrett JW, Braunstein PW: The seat belt syndrome. *J Trauma* 2:220–238, 1962
22. Gerritsen R, Frobese AS, Pezzi PJ: Unusual abdominal injuries due to seat belts. *J Albert Einstein Med Ctr* 14:63–66, 1966
23. Haddad GH, Zickel RE: Intestinal perforation and fracture of lumbar vertebra caused by lap-type seat belt. *N Y State J Med* 67:930–931, 1967
24. Hanson OM, Rasmussen PS: Traffic accident with a spleen injury associated with the use of a safety belt. *Ugeskr Laeg* 125:771–773, 1963
25. Howland WJ, Curry JL, Buffington CB: Fulcrum fractures of the lumbar spine. *JAMA* 193:240–241, 1965
26. Huelke DF, Gikas PW: Causes of deaths in automobile accidents. *JAMA* 203:1100–1107, 1968
27. Hurwitt ES, Silver CE: A ventral hernia following an automobile crash. *JAMA* 194:829–831, 1965
28. Kulowski J, Rost WB: Intra-abdominal injury from safety belt in auto accident: report of a case. *Arch Surg* 73:970–971, 1956
29. LeMire JR, Early DE, Hawley C: Intra-abdominal injuries caused by automobile seat belts. *JAMA* 201:109–111, 1967
30. Lindgren S, Warg E: Seat belts and accident prevention. *Practitioner* 188:467–473, 1962
31. McRoberts JW: Seat belt injuries and legal aspects. *Industrial Med Surg* 34:866–869, 1965
32. Porter SD, Green EW: Seat belt injuries. *Arch Surg* 96:242–246, 1968
33. Quinn FB Jr: Are seat belts enough? *Gen Pract* 26:101–103, 1962
34. Rubovits FE: Traumatic rupture of the pregnant uterus from "seat belt" injury. *Amer J Obst Gynec* 90:828–829, 1964
35. Saldeen T: Fatal neck injuries caused by use of diagonal safety belts. *J Trauma* 7:856–862, 1967
36. Schneider RC, Smith WS, Grabb WC, et al: Lap seat belt injuries: the treatment of the fortunate survivor. *Mich Med* 67:171–186, 1968
37. Schwimmer S, Wolf RA: *Leading Cause of Injury in Automobile Accidents.* Automotive Crash Injury Research. Ithaca, N. Y., Cornell University, 1962
38. Severy DM, Brink HM, Baird JD: *Passenger*

Protection from Front-end Impacts. International Automotive Engineering Congress, Detroit, 1969

39. SMITH WS, KAUFER H: Patterns and mechanisms of lumbar injuries associated with lap seat belts. *J Bone Joint Surg* 51A:239–254, 1969
40. SNYDER RG, SNOW CC, CROSBY WM, et al: Impact injury to the pregnant female and fetus in lap belt restraint In *Proceedings, 10th Stapp Car Crash Conference, 1967.* New York, Society of Automotive Engineers, 1967
41. SNYDER RG, YOUNG JW, SNOW CC, et al: *Seat Belt Injuries in Impact.* Highway Safety Research Institute, The University of Michigan, 1967
42. STAPP JP: Human tolerance to deceleration. *J Aviat Med* 22:42–45, 1951
43. STECKLER RM, EPSTEIN JA, EPSTEIN BS: Seat belt trauma to the lumbar spine: an unusual manifestation of the seat belt syndrome. *J Trauma* 9:508–513, 1969
44. STRAITH CL: Guest passenger injuries. *JAMA* 137:348–351, 1937
45. SUBE J, ZIPERMAN HH, MCIVER WJ: Seat belt trauma to the abdomen. *Amer J Surg* 113:346–350, 1967
46. TOLINS SH: An unusual injury due to the seat belt. *J Trauma* 4:397–399, 1964
47. TOURIN B: Ejection and automobile fatalities. *Public Health Rep* 7B:381–391, 1958
48. TOURIN B, GARRETT JW: *Safety Belt Effectiveness in Rural California Automobile Accidents. Automotive Crash Injury Research.* Ithaca, N. Y., Cornell University, 1960
49. VONBAHR V, ERIKSSON E: Injuries due to the use of safety belts. *Svensk Läraretidning* 58: 141–143, 1961
50. WILLIAMS JS, LIES BA, HALE HW: The automotive safety belt: in saving a life may produce intra-abdominal injuries. *J Trauma* 6:303–313, 1966
51. WILLIAMS RD, SARGENT FT: The mechanism of intestinal injury in trauma. *J Trauma* 3:288–294, 1963
52. WITTE CL: Mesentery and bowel injury from automotive seat belts. *Ann Surg* 167:486–492, 1968
53. WOLF RA: The discovery and control of ejection in automobile accidents. *JAMA* 180:220–224, 1962

ADDENDUM

Seat belt injury case summary as recorded by a letter from James A. Harkins, M.D., February 16, 1970, New London, Connecticut.

The victim was a 29-year-old man who was probably sleeping in the right front seat of a 1963 four-door hard-top Pontiac. The vehicle left the Boston Post Road in the town of Waterford, County of New London and State of Connecticut, striking a fixed object. The vehicle sustained predominantly right front end damage. The speed at impact was estimated to be approximately 35 mph.

Immediately following the accident, the driver unbuckled the seat belt of the passenger. The latter was transported to a hospital, where he was found to have multiple facial lacerations and a fractured nose requiring 60 sutures. Thirteen hours following the accident the patient deteriorated and died. At autopsy he was found to have lacerations of the mesentery of both the small and large bowel, with abrasions and superficial laceration of the right lower quadrant approximately 4 cm above the anterior superior iliac spine.

The victim was most likely asleep and slouched in his seat with his belt well above his iliac crest. At the time of the accident he was thrown forward, striking his head against the windshield, which was starred from impact, and sustained the facial lacerations and fractured nose. The restraining device cut deeply into the abdomen and produced the mesenteric injuries. His death was most likely caused by misdiagnosis.

DISCUSSION

DR. FREDERICK BUNKFELDT, JR. (Milwaukee, Wisconsin): I wish to compliment the authors on the tremendous amount of work they have done, but I think this is only Part I of an excellent paper. A follow-up paper could be done by comparing the results with accidents on a comparable level obtained from the Motor Vehicle Departments. They would be very happy to do this. Then you will be able to tell the value of the seat belts.

DR. WILLIAM M. STAHL (New York, New York): This presentation again affirms the results of the Cornell Crash Survey. That study compared the injuries resulting from specific types of accident, with and without seat belts. It did show the excellent protection afforded by almost any type of restraint.

I have one question. It seems that the failures with the chest belt resulted in severe trauma; in other words, fractures at the fixation point of the lower cervical spine, or complete ejections. This suggests that the cross-chest belt is protective for a more severe accident situation than is the cross-abdominal belt.

Do you have any comparative information on the types of accident in these two groups? That is, do you have any information as to whether failure of cross-chest belts results in more severe injuries than does failure of the cross-seat abdominal belt?

DR. W. G. SCHENK, JR. (Buffalo, New York): I have one comment and one question. I got the impression that the lap belt was not indeed being worn as a lap belt, but as an abdominal belt, and that some of the injuries might not have occurred if the belt had been worn properly.

My other comment was in relation to the cross chest belt. Was this being worn with or without a lap belt?

As we know, the cases of cervical spine injury and decapitation reported by Gikas and others have pointed out that the cross-chest belt worn alone is more of a hazard than a safety feature. I wondered if the authors' experience in relation to these cases of serious injury had indicated that both belts were being worn properly.

DR. JAMES S. WILLIAMS (closing): In answer to the comments of the first speaker, it is difficult to do control studies. We find this information from a number of case records and from accident reports throughout this country and in Europe, so that it is difficult to make any kind of control study and come up with any meaningful answers.

With regard to the comment of the two-point belt being a perhaps more lethal device. This appears to be true in the sense that the severity of accidents was essentially matched in both groups, and yet the severity of injuries in the two-point group was considerably higher.

The comment about the abdominal belt, as indicated by the picture, is true in some cases. The belt was worn high, and therefore the restraining benefits were absorbed by the abdomen itself, and not by the iliac crest. We have three cases in which the wing of the ilium was fractured, but that was the only injury. In those cases the belts were being worn properly.

In answer to the last discusser's question, there have been three additional injuries to pregnant women resulting in a ruptured uterus. There were a total of 26 cases collected by Snyder, and about 50% of these had infant mortality.

A couple of the patients had had previous operations. We found nobody who developed a hernia from this type of injury.

I would hope that, in the future, design of vehicles would be such that the compartment collapse that we have seen will be remedied. We are presently doing a study on 1968 model automobile accidents, and again we find equipment failure. We find compartment collapse and injuries produced by the interior of the vehicle.