AIR BAG COLLISION PERFORMANCE IN A RESTRAINED OCCUPANT POPULATION

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ABSTRACT

For the past five years, the Road Safety and Motor Vehicle Regulation Directorate of Transport Canada has conducted studies of motor vehicle collisions which have resulted in air bag deployments. Canada enjoys high usage of seat belts and, consequently, the vast majority of occupants in the crashes under study were fully restrained. This provided an opportunity to evaluate the effectiveness of air bags as supplemental restraint systems. Results from this process demonstrated that thresholds set by manufacturers for air bag deployment were generally lower than necessary to protect fully restrained occupants. Furthermore, the major drawback of first generation air bags was their aggressivity which often gave rise to air bag-induced injuries to belted occupants. Now, many 1998 vehicles have been equipped with "depowered" air bags. The present paper provides a brief overview of the collision experience with air bags in Canada, and presents some preliminary results from in-depth studies of real world crashes involving second generation air bags.

INTRODUCTION

With the advent of widespread availability of supplementary air bags in Canadian vehicles, Transport Canada initiated a study of real world crashes in which air bags deployed. Starting in October, 1993, eight university-based research teams conducted in-depth collision investigations on convenience samples of such incidents, focusing on crash severity and occupant injury mechanisms (Dalmotas, 1995a).

The air bag study has taken place in three distinct phases. Initially, any air bag deployment crash was included in the study, irrespective of occupant injury outcome. In Phase II of the study, the criteria for inclusion required that an occupant protected by an air bag which deployed in a crash was transported to hospital for examination and/or treatment.

Phase III of the study was recently initiated. The focus of the study has shifted to collisions involving late model vehicles in an attempt to capture incidents involving depowered air bag systems. In Phase III of the study, any crash involving air bag deployment in vehicles less than 3 years in age is captured, these cases being once again independent of injury outcome.

PHASE I AND PHASE II STUDY RESULTS

The initial phase of the air bag study took place between October, 1993 and May, 1995. During this period, a total of 409 air bag crashes were documented. Driver restraint use in the case vehicles was 93% (380). Twenty-three percent (95) of vehicles experienced deployment of passenger air bags, with 36 right front passengers present, 89% (32) of whom were belted.

The second phase of the study was conducted during the period June, 1995 through August, 1997. A total of 309 cases were identified in which an occupant protected by an air bag was transported to hospital following the crash. Seat belt usage by drivers was 87% (268). Sixty-one percent (190) of the vehicles were equipped with dual air bags. There were 92 right front passengers present where passenger bags deployed, 93% (86) of whom were restrained.

Summary information for these two initial phases of the study, providing seat belt usage rates, injury severity and body region, and collision severity, is provided in Tables 1 through 4. As might be expected, given the different case selection criteria, there was a distinct shift towards higher crash severities and greater degrees of injury between Phase I and Phase II of the study. In Phase I, about 75% of case vehicles had estimated barrier speeds (EBS) of 25 km/h or less, compared to about 53% for Phase II. The injury rate for front seat occupants in Phase I was about 65% compared to 92% for Phase II. Face, upper extremity, and lower extremity were the most common injury locations, with an increased percentage of lower extremity injuries and a decreased percentage of facial injuries in Phase II.

Detailed commentary on the results of our earlier field accident investigations, including many case studies, have been reported previously in the literature (e.g. Dalmotas, 1996). The highlights of our findings were as follows:

- Supplementary air bags, in combination with manual seat belts, reduce serious head and facial injuries in high severity crashes.
- There is an increased risk of injury in low severity collisions, especially to the upper extremities and face, over that which would be expected for belted occupants in equivalent crash situations.

Table 1.
Occupants Involved in Air Bag Deployment Crashes

Air Bag Study	Phase I		Phase II		Phase III	
	Driver	Passenger	Driver	Passenger	Driver	Passenger
Total number of cases	409	409	309	309	84	84
Deployments	409	95 (23%)	309	190 (61%)	84	79 (94%)
Front occupants with air bags	409	36 (38%)	309	92 (48%)	84	21 (25%)
Belted front occupants with air bags	380 (93%)	32 (89%)	268 (87%)	86 (93%)	78 (93%)	18 (86%)

Table 2.
Injury Severity for Belted Occupants Involved in Air Bag Deployment Crashes

	Phase I		Phase II		Phase III	
MAIS	Driver	Passenger	Driver	Passenger	Driver	Passenger
0	134 (35%	12 (38%)	22 (8%)	8 (9%)	27 (35%)	4 (22%)
1	217 (57%)	18 (56%)	174 (65%)	55 (65%)	45 (58%)	12 (67%)
2	20 (5%)	1 (3%)	43 (16%)	11 (13%)	3 (4%)	2 (11%)
3	6 (2%)	1 (3%)	15 (6%)	6 (7%)	1 (1%)	-
4	3 (1%)	-	7 (3%)	1 (1%)	1 (1%)	-
5	-	-	4 (2%)	2 (2%)	1 (1%)	-
6	-		2 (1%)	2 (2%)	-	-

Table 3.
Injury Frequency by Body Region for Belted Occupants in Air Bag Deployment Crashes

	Phase I		Phase II		Phase III	
Body region	Driver	Passenger	Driver	Passenger	Driver	Passenger
Head	26 (4%)	-	39 (5%)	12 (5%)	3 (2%)	1 (3%)
Face	166 (26%)	25 (46%)	163 (19%)	74 (29%)	20 (14%)	14 (38%)
Neck	15 (2%)	-	16 (2%)	8 (3%)	-	-
Thorax	67 (11%)	6 (11%)	119 (14%)	35 (14%)	18 (13%)	5 (14%)
Abdomen	19 (3%)	3 (6%)	28 (3%)	13 (5%)	5 (3%)	-
Spine	42 (7%)	-	20 (2%)	10 (4%)	6 (4%)	2 (5%)
Upper Extremities	184 (29%)	10 (19%)	238 (28%)	46 (18%)	57 (40%)	8 (22%)
Lower Extremities	119 (19%)	10 (19%)	215 (26%)	61 (24%)	35 (24%)	7 (19%)

Table 4.
Equivalent Barrier Speeds (EBS) of Case Vehicles

EBS (km/h)	Phase I	Phase II	Phase III
0-15	75 (21%)	24 (9%)	11 (15%)
16-20	117 (33%)	66 (25%)	27 (36%)
21-25	75 (21%)	51 (19%)	21 (28%)
26-30	39 (11%)	47 (18%)	9 (12%)
31-35	27 (8%)	26 (10%)	2 (3%)
36-40	8 (2%)	20 (8%)	1 (1%)
>40	18 (5%)	31 (12%)	4 (5%)

- Females show a higher rate of air bag induced injury in low speed collisions than males, especially with respect to the upper extremities.
- Air bag deployment thresholds are too low for optimal protection of belted occupants.
- Air bag deployment characteristics are overly aggressive for optimal protection of fully restrained occupants.

Of particular concern from the results of our early field studies was a number of cases of air bag induced fatal injuries resulting to occupants involved in minor frontal collisions. Three such cases, involving two drivers and one right front passenger, have been reported previously in the literature (Dalmotas, 1995b; McClafferty, 1997; German, 1997). Since the publication of these cases, two additional driver fatalities have been identified. These two cases are briefly reviewed below:

ACR3-1919: A 1996 Lexus ES300 was travelling southbound on a snow and ice covered residential street. The driver failed to negotiate a left curve and ran off the road to the right. The vehicle travelled across the lawn of a residence, striking a small sapling, breaking through two wooden fences, and finally impacting the corner of a garage (12FLEW1). The latter impact resulted in the deployment of both front air bags.

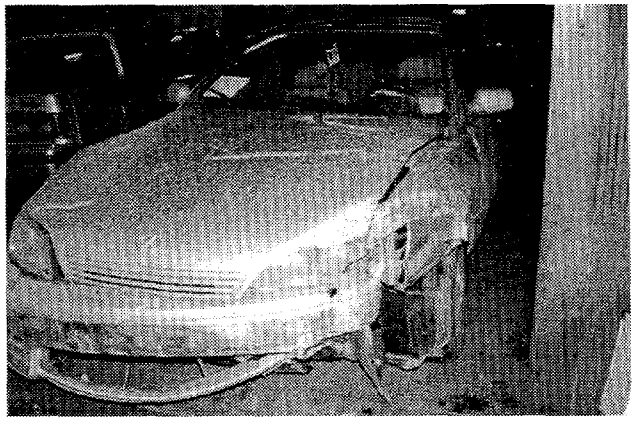

Figure 1. 1996 Lexus ES300.

The driver of the Lexus (44 years, female, 157 cm, 53 kg) was using the available three-point seat belt system. The investigating police officer indicated that the driver's seat was positioned close to the steering wheel. Subsequent detailed examination of the air bag assembly identified cosmetic transfers on both the air bag cover and fabric. These witness marks indicated that the driver's head was in extremely close proximity to the air bag module at the time of deployment.

The driver was unresponsive at the collision scene. She was transported to hospital where attempts at resuscitation were unsuccessful. No autopsy was conducted. The cause of death was stated as closed head injury. Other recorded injuries were contusions to the face, chest, and upper right arm, and a burn to the middle and index fingers of the left hand.

ASF2-1505: A 1992 Ford Tempo was travelling southbound along a two-lane, undivided rural highway. The road was wet as there was light precipitation. A vehicle ahead of the Tempo braked. The Tempo's driver also braked, but lost directional control. The car crossed the centre line and entered the east ditch. The front of the Tempo struck the back slope of the ditch (12FDEW1) at which point the driver's air bag deployed.

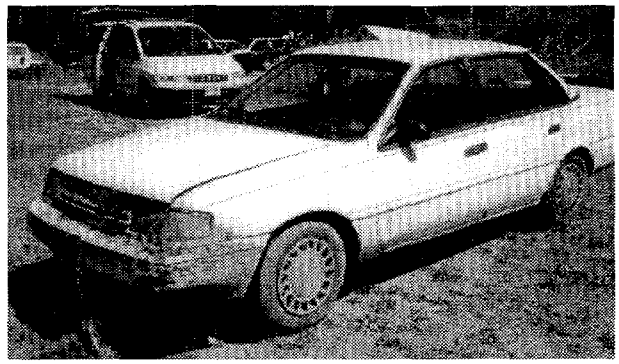

Figure 2. 1992 Ford Tempo.

The driver (79 years, female, 155 cm, 77 kg) was fully restrained with her seat in the forward of middle position. Emergency medical personnel arrived within 15 minutes of the collision. The driver was coherent and complaining of chest pain. She was removed from the vehicle and transported to hospital. Later the same day, medical complications arose and the driver was transported to a trauma centre where she died early the next morning. The driver sustained a comminuted fracture of the left lateral mass of C1, multiple bilateral rib fractures, a lacerated aorta, a fractured sternum, minor contusions, lacerations and abrasions to the face, chest and extremities.

PHASE III STUDY RESULTS

The third phase of the study was commenced in September, 1997. To date a total of 84 cases have been investigated. Summary data for this current phase of the study are included in Tables 1 through 4.

It is interesting to note that in the 84 collisions studied, 94% (79) case vehicles were equipped with dual air bags. This underscores the increasing availability of supplementary air bags in the vehicle fleet.

At the present time, the small number of cases with depowered air bags and the number of vehicle occupants in this latest phase of the air bag study precludes drawing any firm conclusions as to the effectiveness of recent air bag designs. Furthermore, in reviewing the data presented in the tables, one must consider that included is a mix of 1996-97 model year vehicles with first generation air bags, and 1998 model vehicles, most of which were equipped with depowered air bag systems.

Given the very limited data which are currently available it is instructive to extract the subset of 1998 model year vehicles which are known to have been equipped with second generation air bags. Amongst the cases in the current study were 17 vehicles of model year 1998. Ten of these vehicles were determined to have been equipped with depowered air bags. The following case studies highlight the findings with respect to these latter vehicles:

ACR4-1108: A 1998 Ford Contour was turning left out of a parking lot. The Contour's driver observed a vehicle approaching from her left, but believed she had sufficient time to complete the turn. The driver of the oncoming 1990 Oldsmobile Ciera braked but was unable to avoid a collision. The front of the Ciera (12FYEW1) struck the left rear quarter panel of the Contour (09LZEW2). Both front air bags in the Contour deployed.

Figure 3. 1998 Ford Contour

The Contour's driver (54 years, female, 157 cm, 54 kg) was fully restrained, with her seat adjusted to the forward of middle position. The driver sustained contusions over the hips and left shoulder as a result of seat belt loading, a contusion to the right elbow from contact by the deploying air bag, and a contusion to the left knee from contact with the door interior (MAIS 1).

ACR4-1117: The case vehicle, a 1998 Dodge Neon, was travelling northbound on a two-lane, undivided, urban collector in foggy conditions. The car came up to a Y-intersection where its right front end struck a utility pole in the gore area. The pole penetrated completely through the vehicle's structure (01FRAW9). The front portion of the vehicle continued ahead and rolled down an embankment; the rear portion remained close to the pole.

The driver (25 years, male, 180 cm, 99 kg) was belted and seated fully rearward. Both front air bags in the case vehicle deployed. The driver was fatally injured in the crash. He suffered an open skull fracture, right haemothorax, a fracture to the right humerus, and fractures to both lower legs (MAIS 5).

Figure 4. 1998 Dodge Neon

ACR4-1308: A 1998 Acura 1.6 EL was travelling westbound along an urban street at night. The driver slowed down as she approached an intersection, as the traffic light was red. At the same time, a 1978 John Deere snow plow was heading northbound on the intersecting street. The driver of the snow plow intended to turn right at the intersection but, due to the slippery road, the vehicle rotated 180 degrees clockwise, and its left rear wheel struck the front of the Acura (12FDEW1). Both front air bags in the Acura deployed in the impact.

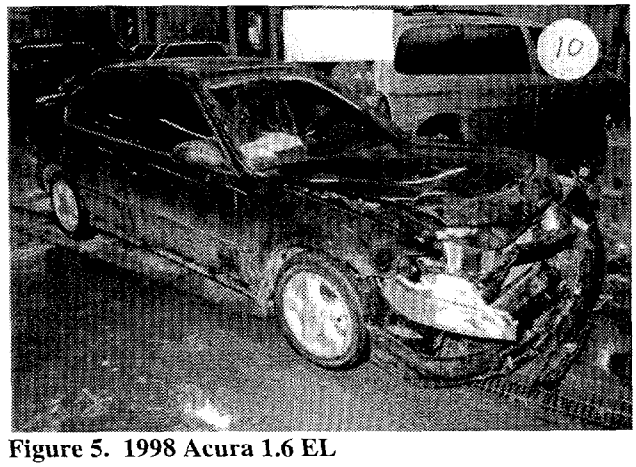

Figure 5. 1998 Acura 1.6 EL

The fully restrained driver of the Acura (20 years, female, 160 cm, 53 kg) had her seat adjusted in the forward of middle position. She received a sprained left shoulder (MAIS 1) due to seat belt loading. She also complained of pain to the chest, neck, back, both hands and chest.

The fully restrained, right front passenger in the Acura (22 years, male, 178 cm, 75 kg) had his seat adjusted rearward of middle. He sustained a contusion to his right hip due to seat belt loading (MAIS 1). Following the crash, this occupant fell to the ground, possibly losing consciousness for several seconds. He received a facial contusion as a result of striking the ground.

ACR4-1309: At the end of an afternoon, a 1998 Pontiac Sunfire was travelling southbound along a four-lane undivided city street. The Sunfire's driver was alcohol impaired and allowed his vehicle to travel into the northbound passing lane. The driver of an oncoming 1990 Chevrolet Cavalier swerved to the left, trying to avoid a collision; however, the right front corner of the Sunfire sideswiped the right side of the Cavalier. As a result of this impact, both the Sunfire's front air bags deployed. As the Sunfire continued past the Cavalier, it came into a head-on crash with a 1991 Ford F-350 pickup truck which had been following the Cavalier. This impact resulted in extensive crush to the front structure of Sunfire, and overriding of the front bumper (12FDEA4).

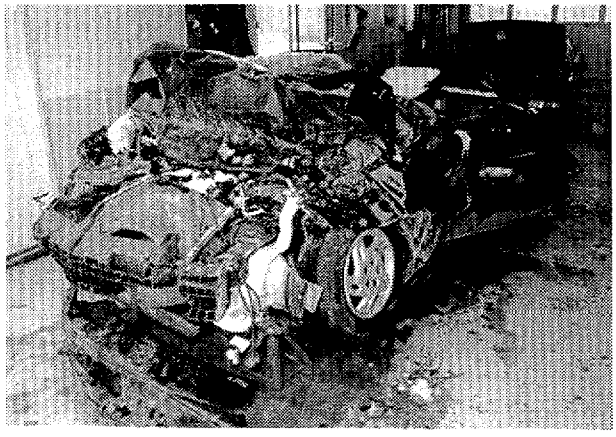

Figure 6. 1998 Pontiac Sunfire

The driver of the Sunfire (38 years, male, 191 cm, 90 kg) was fully restrained and was sitting in the rearward of middle position. He sustained fatal injuries (MAIS 5) in the collision with the pickup truck, as a result of major loading to his chest by his vehicle's steering wheel, which was severely deformed. He suffered multiple bilateral rib fractures, lacerations to the heart and vena cava with haemo-mediastinum, and multiple lacerations to the liver with haemo-peritoneum. He also sustained a contusion to the scalp and lacerations to the right knee.

ACR4-1506: The driver of a 1998 Ford Explorer was attempting to turn left at an intersection with a busy arterial roadway. In his haste to complete the turning manoeuvre he cut the corner too sharply and the left front end of his vehicle struck a utility pole at the edge of the median (12FLEN1).

Figure 7. 1998 Ford Explorer

The driver (29 years, male, 180 cm, 73 kg) was fully restrained with his seat positioned rearward of middle. Both air bags in the utility vehicle deployed. The driver was uninjured (MAIS 0).

ACR4-1508: A 1998 Jeep Grand Cherokee was travelling southbound on an urban arterial at night. Snow was falling and the road was wet with icy sections. The vehicle entered a moderate downgrade at which point the driver lost directional control. The Cherokee rotated clockwise through 360 degrees and its front bumper struck (11FDEW2) a retaining wall on the west side of the road. Both air bags in the vehicle deployed in the impact.

Figure 8. 1998 Jeep Grand Cherokee

The driver (26 years, male, 188 cm, 91 kg) was accompanied by a right front passenger (33 years, female,

173 cm, 68 kg). Both occupants were fully restrained. The driver's seat was fully rearward, while the passenger's seat was in the middle position.

Both occupants braced prior to impact with the wall. The driver was uninjured (MAIS 0). The passenger, sustained abrasions to both thighs from contact by the air bag (MAIS 1). She also complained of numbness to the left nostril and of lower back pain.

ACR4-1512: A 1998 Ford Mustang was travelling southbound along a four-lane undivided road. The roadway was snow covered and rain was falling. While attempting to turn left into a private driveway the driver lost directional control. The vehicle mounted the east curb where its front end struck a group of small trees and metal posts (12FDEW2).

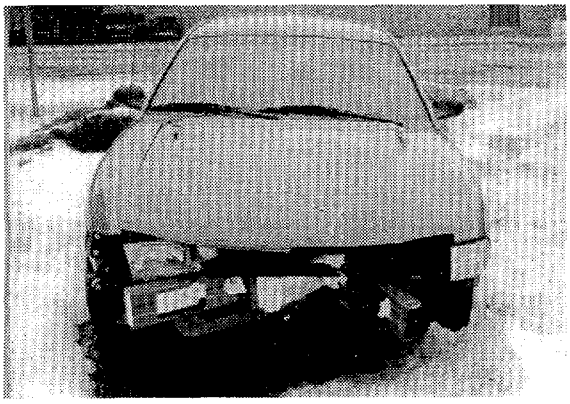

Figure 9. 1998 Ford Mustang

The driver (46 years, male, 178 cm, 70 kg) was fully restrained with his seat in the middle position. He complained of soreness to his neck and back (MAIS 0).

ACR4-1513: A 1988 Acura Legend was travelling westbound in the driving lane of a freeway and was being followed by the case vehicle, a 1998 Chevrolet Cavalier. The road was congested and, as the Acura approached an entrance ramp, traffic ahead slowed to a stop.

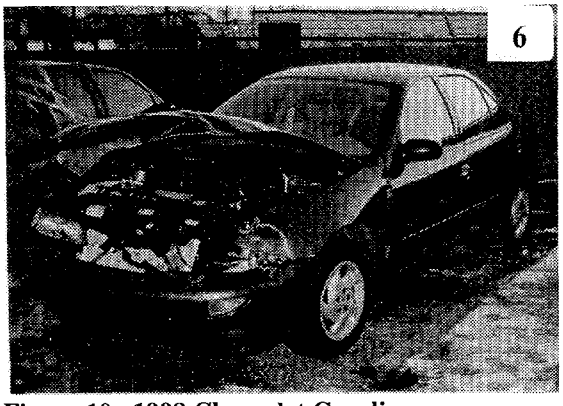

Figure 10. 1998 Chevrolet Cavalier

The Acura's driver brought his vehicle to a halt. The driver of the Cavalier braked, but the front of his vehicle (12FDEW1) struck the rear of the Acura (06BDLW1).

The fully restrained driver (40 years, male, 170 cm, 65 kg) of the Cavalier had his seat adjusted close to the middle position. Both front air bags deployed. The driver was uninjured (MAIS 0).

ACR4-1516: A 1998 Honda Civic was travelling northbound along an urban collector road and was in the process of passing a stationary transit bus. A 1991 Toyota Previa entered the roadway from a private driveway just ahead of the bus. The right front end of the Civic (01FZEW1) struck the left front corner of the Previa (10LFEW1).

Figure 11. 1998 Honda Civic

The Civic's driver (22 years, male, 188 cm, 77 kg) was belted with his seat in the rearward of middle position. He braked prior to impact and held on tightly to the steering wheel. He complained of soreness to his nose as a result of contact by the air bag but no specific injury was documented (MAIS 0).

The right front passenger (23 years, female, 163 cm, 57 kg) in the Civic was belted with her seat fully rearward. She sustained multiple facial abrasions as a result of contact with the air bag (MAIS 1).

ACR4-1607: The case vehicle, a 1998 Dodge Neon, was travelling along a two-lane, undivided, rural arterial. As the Neon approached an oncoming GMC pickup truck, a small utility trailer being towed by the truck began to jacknife. The trailer hitch released, the safety chains failed, and the trailer became airborne across the roadway. The driver of the Neon braked, but the trailer struck the left front wheel and fender of the vehicle (12FLHN6). The impact resulted in the deployment of both front air bags in the Neon.

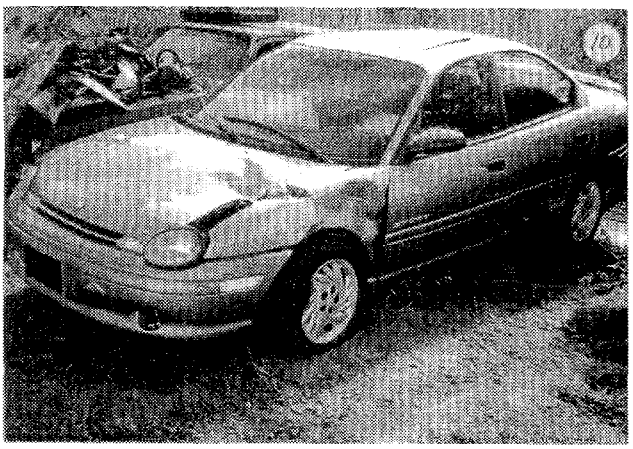

Figure 12. 1998 Dodge Neon

The driver of the Neon (44 years, female, 173 cm, 86 kg) was belted with the seat adjusted rearward of middle. She received contusions to two fingers on the left hand due to contact by the air bag (MAIS 1). She also reported redness to her face, and apparent fading of her hearing in the right ear immediately post-crash.

ACR4-1612: A 1998 Chevrolet Cavalier was travelling northbound in the curb lane of a four-lane urban arterial. A pickup truck which was overtaking the Cavalier moved abruptly into the curb lane.

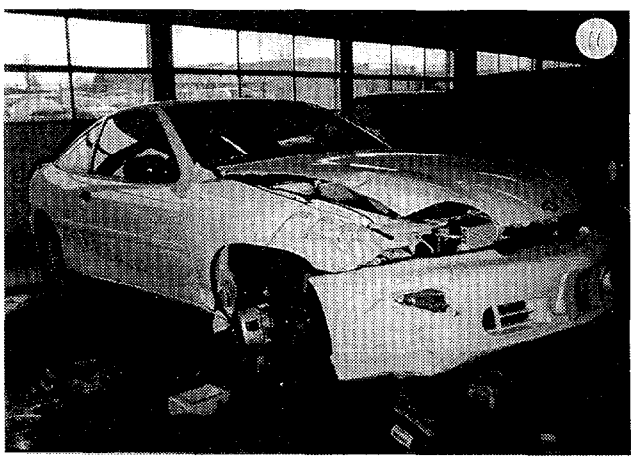

Figure 13. 1998 Chevrolet Cavalier

The driver of the Cavalier steered to the right to avoid a hitting the truck. The front of the Cavalier (12FREE3) struck a wooden utility pole which caused both front air bags to deploy.

The Cavalier's driver (16 years, female, 165 cm, 52 kg) was fully restrained and was uninjured (MAIS 0).

CONCLUSIONS

In the early stages of our study, the benefits of supplementary air bags were demonstrated, largely through a reduction in the incidence of serious head injuries in high severity crashes. Nevertheless, a number of drawbacks with early air bag system designs were also identified. In particular, there was an elevated risk of injury in minor to moderate collisions. Whereas most such injuries were minor, occasionally severe and even fatal injuries were experienced in low severity crashes.

In particular, some of the injury patterns were not normally seen for belted occupants in equivalent collision situations. Another unusual feature of air bag/occupant interactions was an elevated risk of injury to females. This has resulted in Canada pursuing a possible regulation using 5th percentile dummies with the seats in the fully forward position (Dalmotas, 1996).

The data resulting from the Canadian study have been analyzed and published on a continuing basis. The results of the research have been utilized in promoting effective use of occupant restraint systems, both seat belts and child restraints, while taking into account the availability of supplementary air bags.

Guidelines by which motor vehicle occupants might minimize the risk of air bag induced injury were published by Transport Canada and widely distributed. These included: ensuring that a seat belt was always correctly used; adjusting the occupant's seat to be as far rearward as practicable; placing children under the age of 12 years in the rear seat, secured by an appropriate occupant restraint system; and never placing a rear-facing infant carrier in a right front passenger seat where an air bag was installed.

The study data have also been shared with the automobile manufacturers and air bag suppliers. In September, 1996 the Minister of Transport wrote to the vehicle manufacturers asking them to work urgently with Transport Canada to improve air bag collision performance. In November of the same year, the domestic manufacturers announced that they would introduce less aggressive air bags in Canadian vehicles, improve labelling, and proactively notify customers of safety issues related to air bag systems. This announcement was quickly followed by similar action on the part of vehicle importers. As a result, second generation air bags have been installed in many Canadian vehicles, commencing in the 1998 model year. These new air bags have less powerful deployment characteristics than earlier systems, through a combination of system redesign, and/or the use of less propellant.

While the number of crashes involving depowered air bag systems which have been investigated to date remains small, the preliminary results are encouraging. Two drivers were fatally injured; however, both instances resulted from the nature and severity of the collisions, rather than being influenced by the depowering of the air bags. One case involved destruction of the structural integrity of the vehicle. The other saw the driver's air bag deploy in an initial, rather minor impact, such that it was

unavailable to him for a subsequent severe head-on crash. The remaining incidents were all collisions of minor severity. In these non-fatal crashes, there were a total of 12 front seat occupants (9 drivers and 3 right front passengers). All 12 occupants were belted. Eight individuals (7 drivers and 1 passenger) were uninjured, while the remaining 4 occupants (2 drivers and 2 passengers) received minor contusions or abrasions due to contact with the air bag.

Despite, the introduction of second generation air bags into new vehicles in Canada, concern remained with respect to certain occupants of vehicles in the existing fleet. This was particularly the case for a small group of occupants who, for various reasons, were unable to follow the safety precautions suggested by Transport Canada with respect to minimizing the risk of air bag induced injury. The Minister again contacted automobile manufacturers and requested that they take steps to deal with such consumers. Agreement was reached between the federal government, the governments of the provinces and territories, and the automobile manufacturers, on a national programme for air bag deactivation. This programme was announced by the Minister in February, 1998.

Situations where individuals are deemed to be at risk are: children in rear-facing infant carriers which must be installed in the right front passenger seat, i.e. in pickup trucks and sports cars; children who must occupy the right front passenger seat, as is sometimes the case in car pools; drivers who are unable to attain a seating position with at least 25 cm of clearance between their chest and the steering wheel; and occupants having a specific medical problem requiring deactivation of the air bag.

The deactivation process is one of informed consent, where concerned individuals are provided safety information indicating both the benefits and drawbacks of air bag systems, and underscoring the implications of deactivating the air bag. Individuals who believe that they would benefit from deactivation complete a form certifying that they fit into one of the categories of individuals at risk and that they fully understand the consequences of deactivating the air bag. The completed form is returned to the government which reviews the information provided and returns the form, acknowledging its proper completion. The consumer may then take this form to a vehicle service centre to have the deactivation procedure performed. Finally, the servicing technician completes the form, indicating the manner in which deactivation was performed, and returns the form to the government for retention.

It is anticipated that most air bag deactivations will be accomplished through the installation of a manual cut-off switch with telltale warning lights. This method is preferred as it allows the air bag to be temporarily deactivated for a specific individual at risk, while retaining the option for readily enabling the air bag system should another occupant desire the supplementary protection which the air bag offers.

Transport Canada's study of the real world collision performance of air bag systems continues, as does our effort to improve air bag design through a programme of crash testing and research. As more knowledge and expertise is developed, air bag systems will become more intelligent. It is hoped that advanced technologies will address the safety issues associated with these systems.

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The conclusions reached, and opinions expressed, in this paper are solely the responsibility of the authors. Unless otherwise stated, they do not necessarily represent the official policy of Transport Canada.

REFERENCES

Dalmotas DJ, German A, and Welbourne ER, "Directed Studies: A Focused Approach to Collision Investigation", Proc. CMRSC-IX, pp. 13-23, Montréal, Québec, 1995a.

Dalmotas DJ, German A, Hendrick BE, and Hurley RM, "Air Bag Deployments: The Canadian Experience", J.Trauma, April, 1995b.

Dalmotas DJ, Hurley J, German A and Digges K, "Air Bag Deployment Crashes in Canada"; Proc. 15th. ESV Conf., pp. 155-168, 1996.

McClafferty KJ, Chan J, Shkrum MJ, and German A, "A Multi-Disciplinary Study of a Canadian Air bag Fatality", Proc. CMRSC-X, Toronto, Ontario, pp. 118-127, June, 1997.

German A, Dalmotas DJ, Hurley RM, and Szentmiklosy AM, "Field Accident Experience with Passenger Air Bags in Canada", Proc. CMRSC-X, Toronto, Ontario, pp. 128-138, June, 1997.