

## INVESTIGATIONS OF CRASHES INVOLVING PREGNANT OCCUPANTS

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### ABSTRACT

Case reports of 16 crashes involving pregnant occupants are presented that illustrate the main conclusions of a crash-investigation program that includes 42 crashes investigated to date. Some unusual cases that are exceptions to the overall trends are also described. The study indicates a strong association between adverse fetal outcome and both crash severity and maternal injury. Proper restraint use, with and without airbag deployment, generally leads to acceptable fetal outcomes in lower severity crashes, while it does not affect fetal outcome in high-severity crashes. Compared to properly restrained pregnant occupants, improperly restrained occupants have a higher risk of adverse fetal outcome in lower severity crashes, which comprise the majority of all motor-vehicle collisions.

An understanding of how pregnant women and their fetuses are injured in crashes is necessary to help vehicle restraint designers improve protection for pregnant occupants and reduce adverse fetal outcomes. A summary of the literature on automotive trauma in pregnancy is by presented by Klinich et al. (1998); additional studies not included in this summary are presented by Aitokallio-Tallberg and Halmesmaki (1997), Baethmen, et al. (1996), Crosby and Costiloe (1971), Fildes, et al. (1992), Lane (1989), Schultze, et al. (1998), and Wolf, et al. (1993). These resources describe many case studies and some epidemiological data on pregnant women involved in automotive crashes. However, these studies do not provide reliable estimates of the crash type and severity, or detailed information about the vehicle damage or occupant restraint use, and they are generally biased toward negative fetal outcomes.

A crash-investigation project was undertaken at the University of Michigan to obtain a better understanding of the factors

involved in fetal loss to pregnant occupants in motor-vehicle crashes. In-depth investigations of real-world crashes involving pregnant occupants were conducted and a database with quantitative crash information plus detailed information on maternal and fetal injuries and outcomes has been established. The results help identify safety issues and mechanisms of fetal injury and loss, and provide case data for validating injury criteria for a new pregnant crash dummy with improved anthropometry, biofidelity, and injury assessment capabilities.

The new University of Michigan Transportation Research Institute (UMTRI) database of pregnant occupants involved in crashes is unique because it includes cases with a wide range of fetal outcomes, including many cases with good outcomes that have not generally been reported in the literature. The belt-restraint usage rate of occupants in the database is representative of usage rates in the general occupant population [NHTSA 1998], and the database includes a significant number of pregnant occupants exposed to airbag deployments. A key strength of the database is the inclusion of crash severity estimates based on vehicle damage measurements. In addition, the UMTRI database includes detailed information on the fetal outcome that is missing from the National Automotive Sampling System (NASS) crash data.

This paper provides detailed descriptions of selected crashes that illustrate the main conclusions of the study [Klinich, Schneider, Moore, and Pearlman, 1999]. In addition, some cases describing exceptions to these conclusions are presented.

## METHODS

Investigators were notified of crashes involving pregnant occupants from medical staff of trauma centers, law enforcement agencies, or respondents to advertisements placed in medical publications. Eighty-seven notifications of crashes involving pregnant occupants were received over the course of this 30-month project, from which forty-two crashes were investigated. Two-thirds of the notifications were from locations within 50 miles of Ann Arbor, MI. Crashes were excluded from investigation if the case occupant was less than twenty weeks pregnant ( $n=10$ ) or if the occupants did not agree to participate ( $n=29$ ). Crashes were also not investigated if they involved multiple impacts or vehicle rollovers ( $n=6$ ) because of difficulty in determining which interior contact points are associated with particular injuries.

The forty-two investigated crashes, involving forty-three pregnant occupants, were classified into twenty-seven major investigations and fifteen minor investigations. An investigation was considered minor if medical records were not available to confirm

maternal and fetal outcome or the vehicle was not available for inspection. Standard UMTRI crash investigation techniques were used for the major investigations. Information about the crash circumstances and conditions was determined, the crash scene and external vehicle and internal vehicle damage were measured and photographed, and detailed occupant and fetal data and injuries were obtained from medical records and subject interviews. Crush measurements were input to the WinSMASH program to estimate impact severity.

For comparison purposes, impact severity was categorized as minor (<24 kph), moderate (24 to 48 kph), or severe (>48 kph), regardless of impact direction. A maternal injury rating was developed based on the injury severity score (ISS) [Baker et al. 1974], excluding injuries to the placenta or uterus, which were considered fetal injuries in this study. A minor maternal injury rating is assigned to ISS scores less than 10, a moderate rating to ISS scores from 10 to 20, and a major rating to ISS scores greater than 20. Fetal outcomes were categorized as good, minor fetal complications, major fetal complications, or fetal loss. Minor complications include early contractions or delivery within 48 hours of the crash at a gestational age of at least 32 weeks. Major fetal complications include placental abruption (separation of placenta from the uterus), uterine laceration, direct fetal injury, or premature delivery within 48 hours of the crash before 32 weeks gestational age. Adverse fetal outcomes are defined as fetal loss or major complications, while acceptable fetal outcomes include good fetal outcomes or minor complications.

## RESULTS

**OVERALL RESULTS.** A complete analysis of the entire database is reported in Klinich et al. (1999) and is briefly summarized here. The distribution of adverse and acceptable fetal outcomes by impact severity and maternal restraint use for 43 pregnant occupants is shown in Figure 1. Figure 2 shows the percent of adverse fetal outcome for each grouping in Figure 1. Crash severity has the strongest effect on fetal outcome, with greater crash severities associated with higher percentages of adverse fetal outcomes. In this study, all of the severe crashes had adverse fetal outcomes. Maternal restraint use also has a significant effect on fetal outcome, with proper restraint use (three-point belt with or without airbag) associated with higher percentages of positive fetal outcomes, especially in lower severity crashes. Although limited by sample size, outcomes to mothers restrained by a three-point belt versus a three-point belt and airbag indicate that airbags may have a positive effect on fetal outcome. As shown in Figure 3, maternal injury level has a significant effect on fetal outcome, with a higher percentage of

adverse fetal outcomes occurring with increasing levels of injury to the mother. Impact direction, occupant seating position, gestational age, maternal stature, and maternal weight do not have statistically significant effects on fetal outcome in this database.

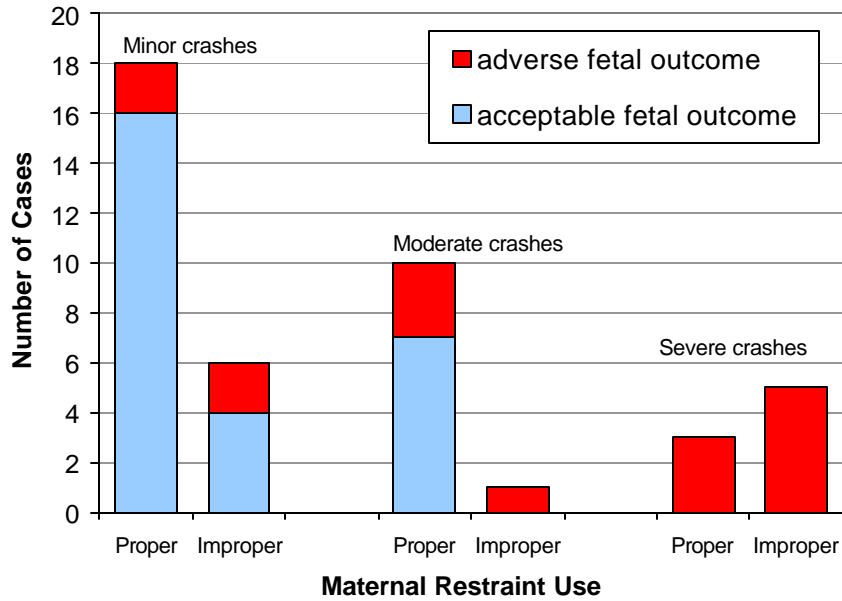


Figure 1. Distribution of fetal outcome by crash impact severity and maternal restraint. Use of a three-point belt, with or without airbag deployment, is considered proper restraint in this study; all other restraint combinations are considered improper.

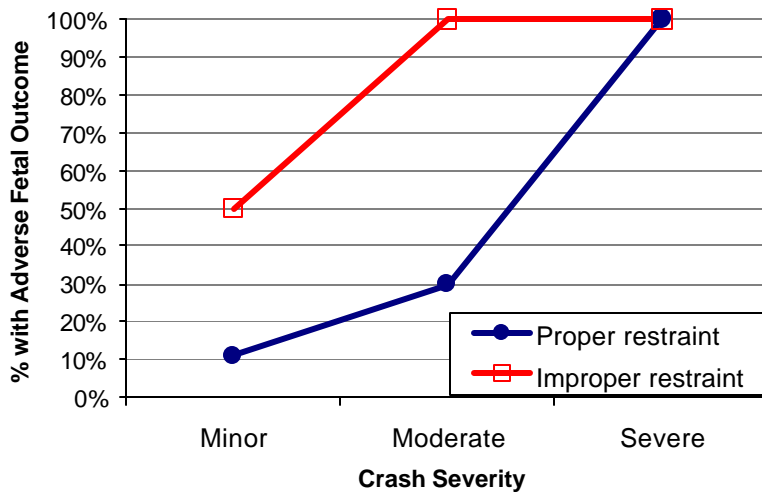


Figure 2. Percentage of cases with adverse fetal outcome at each crash severity level according to maternal restraint.

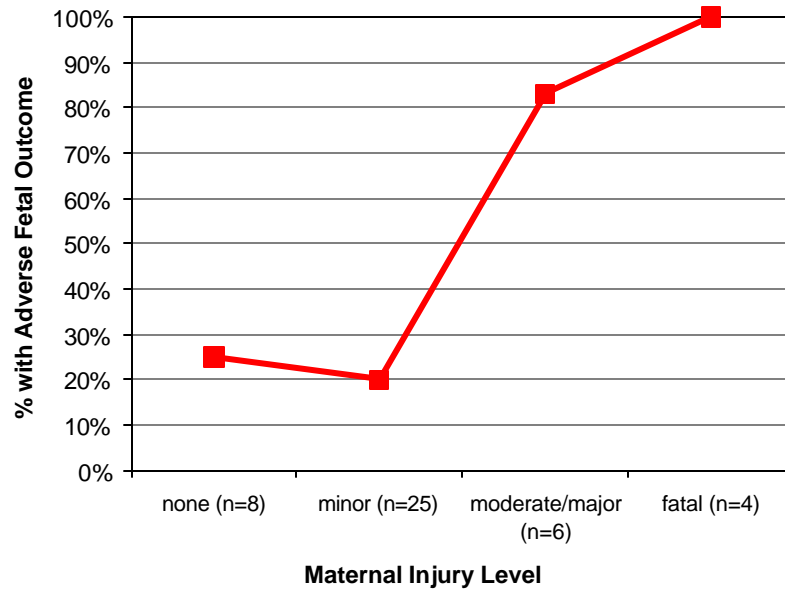


Figure 3. Percentage of cases with adverse fetal outcome at each maternal injury level.

The following case descriptions, ordered by impact direction and crash severity, illustrate these main findings, as well as some exceptions.

**SEVERE FRONTAL IMPACT TO BELT-RESTRAINED DRIVER WITH FETAL LOSS (GMP-010).** A 1992 Saturn SL2 (Figure 4), driven by a 30-year-old pregnant female, was involved in an extremely severe head-on crash with a 1987 Ford Mustang when the Saturn crossed the centerline and struck the Mustang in an offset mode. The delta V is estimated to have been approximately 71 kph. There was extensive intrusion into the driver's seating area. The 30-year-old driver of the Saturn (175 cm, 90 kg) was 40 weeks pregnant. She was wearing the automatic shoulder belt and the manual lap belt at the time of this severe crash. It took the rescue crew approximately 45 minutes to extricate her from the vehicle. Upon arrival at the hospital, an ultrasound showed no fetal heart tones or activity. The fetus died in utero as a result of placental abruption before arrival at the hospital.

The belt-restrained pregnant driver sustained multiple facial and lower extremity injuries that included fractures. She also had contusions to her chest and abdomen showing evidence of belt use. Maternal ISS was 29. It is suspected that abdomen contact with the steering wheel or lap belt resulted in the placental abruption (AIS 4) and fetal loss. The mother recovered from her injuries.



Figure 4. Damage to 1992 Saturn SL2 in case GMP-010, with roof removed by emergency personnel. CDC: 12-FYEW-5; maximum crush: 125 cm.

**MODERATE FRONTAL IMPACT TO BELT- AND AIRBAG-RESTRAINED RIGHT-FRONT PASSENGER WITH GOOD FETAL OUTCOME (GMP-023).** At an intersection, a 1991 Chevrolet Caprice made a left turn in front of the case vehicle, a 1996 Nissan Maxima. The pregnant occupant was the right-front passenger in the Maxima, which struck the right side of the Caprice with its front (Figure 5). The equivalent barrier speed is estimated to have been approximately 24 kph. The 24-year-old right-front passenger (163 cm, 64 kg) was 37 weeks pregnant. She was wearing the three-point belt and the airbag deployed, and she reportedly had the seat in the full-rearward seat-track position.



Figure 5. Damage to 1996 Nissan Maxima in case GMP-023. CDC: 12-FDEW-2; maximum crush: 32 cm.

Measurements were taken of the seat position after the impact, and the mother was subsequently photographed and measured in the vehicle at this reported seating position, as shown in Figure 6. The front of her abdomen and her knees were approximately 44 and 28 cm from the instrument panel, respectively. In addition to numerous AIS 1 contusions and abrasions, she sustained an AIS 2 fracture to her sternum from loading by the shoulder portion of the three-point belt.

After the crash, she was transported to the hospital by ambulance. The fetus was monitored and maintained a normal heart rate, so the mother was discharged home about 24 hours after the

crash. Approximately 2 weeks after the crash, at a gestational age of 39 weeks, she delivered a healthy baby.



Figure 6. Case occupant in reported approximate position and posture at the time of the crash for case GMP-023.

**MODERATE FRONTAL IMPACT TO BELT- AND AIRBAG-RESTRAINED DRIVER WITH GOOD FETAL OUTCOME (GMP-025).** Weather conditions were good when the case vehicle, a 1998 Dodge Stratus (Figure 7), struck a stopped 1996 GMC K1500 pickup in the rear. The equivalent barrier speed is estimated to have been approximately 28 kph. The 35-year-old female (163 cm, 66 kg) driver was 39 weeks pregnant and she reportedly had the seat in the midtrack position. She was wearing the three-point belt and the airbag deployed. She sustained AIS 1 contusions to her extremities. After the crash, the fetus maintained a normal heart rate, and the pregnant driver was discharged within 24 hours of the crash. Two weeks after the crash, at a gestational age of 41 weeks, she delivered a healthy baby.



Figure 7. Damage to 1998 Dodge Stratus in case GMP-025. CDC: 12-FDEW-2; maximum crush: 40 cm.

**MODERATE FRONTAL IMPACT TO BELT- AND AIRBAG-RESTRAINED RIGHT-FRONT PASSENGER WITH MAJOR FETAL COMPLICATIONS (GMP-026).** This crash occurred on a two-lane, rural roadway. A 1994 Mitsubishi Gallant struck the front of the case vehicle shown in Figure 8, a 1998 Chevrolet Cavalier. The delta V is estimated to have been about 41

kph. The 18-year-old female (152 cm, 68 kg), right-front passenger was wearing the three-point belt and the passenger frontal-impact airbag deployed. She was 30 weeks pregnant, and reported that the seat was in the full-rearward track position. When she saw the impending collision, she reportedly braced herself by placing her right hand on the instrument panel and her feet against the toepan. In addition to numerous abrasions and contusions, she suffered an AIS 3 radius fracture and AIS 2 tibia and fibula fractures.



Figure 8. Damage to 1998 Chevrolet Cavalier in case GMP-026. CDC: 12-FDEW-3; maximum crush: 57 cm.

Approximately 9 weeks after the crash, at a gestational age of 39 weeks, the mother delivered a 2.52 kg baby. The infant sustained a right clavicle fracture as a result of difficult birth. The infant was admitted to the hospital after 7 days for evaluation of a small head circumference. A CT scan of the brain revealed ventricular cranial synostosis, right frontal and left parietal encephalomalacia, sagittal and left lambdoidal synostosis, and an enlarged ventricle. These complications are suspected to have resulted from the trauma of the crash based on similarities to a case reported in the literature [Gabis 1997] with more extended documentation of fetal status before and after the crash.

**MINOR FRONTAL IMPACT TO UNRESTRAINED RIGHT-FRONT PASSENGER WITH GOOD FETAL OUTCOME (GMP-003).** The front of a 1986 Ford Tempo (Figure 9) struck the rear of a 1984 Mercedes-Benz that had stopped for traffic. The equivalent barrier speed for the Tempo is estimated to have been about 12 kph. An unbelted 18-year old female (157 cm, 70 kg), who was 39 weeks pregnant, was seated in the right front of the Tempo, and she sustained AIS 1 head and back injuries. Initial diagnosis of the fetus was good. The infant was delivered 16 days after the crash at 41 weeks gestational age. The infant was discharged in healthy condition after treatment for a cleft palate unrelated to the crash.





Figure 9. Damage to 1986 Ford Tempo in case GMP-003. CDC: 12-FYEW-1; maximum crush: 6 cm.

**MINOR FRONTAL IMPACT TO AIRBAG-RESTRAINED DRIVER WITH GOOD FETAL OUTCOME (GMP-005).** A 1996 Toyota Corolla, driven by a 23-week pregnant female, struck the rear of a 1989 Ford LTD Crown Victoria that stopped quickly on a wet road. The delta V of the Corolla shown in Figure 10 is estimated to have been approximately 12 kph. The 30-year-old (175 cm, 102 kg) driver was not wearing the three-point belt, but the airbag deployed. Measurements were taken of the seat position after the impact, and the mother was subsequently photographed and measured in the vehicle at this seating position, as shown in Figure 11. With these settings, the front of her abdomen was approximately 14 cm from the bottom of the steering-wheel rim. She sustained AIS 1 injuries to her chest, head, and knee.



Figure 10. Damage to 1996 Toyota Corolla in case GMP-005. CDC: 12-FREW-1; maximum crush: 21 cm.



Figure 11. Approximate occupant position at the time of the crash in case GMP-005.

Measurement of fetal heart rate after the crash was normal, and the occupant was discharged within 12 hours of the crash. At 41 weeks gestation, she delivered by cesarean section because of failure to progress. No neonatal injuries resulted from the motor-vehicle crash.

**MINOR FRONTAL IMPACT TO BELT- AND AIRBAG-RESTRAINED DRIVER WITH MAJOR FETAL COMPLICATIONS (GMP-006).** The front of a 1993 Dodge Caravan was struck by a 1992 Chevrolet Cavalier traveling in the opposite direction when the pregnant driver of the Caravan attempted to make a left turn. At the time of the vehicle inspection, the front bumper, grille and left-front fender were detached from the Caravan and unavailable for inspection (Figure 12). The estimated equivalent barrier speed is less than 24 kph. The 27-year-old female (170 cm, 91 kg) driver was 35 weeks pregnant at the time of the crash. She was wearing the three-point belt and the airbag deployed. In addition to AIS 1 contusions, she sustained two horizontal lacerations approximately 6.4 cm apart on the left posterior side of the uterus (AIS 3), apparently from indirect loading of the lap belt. A partial abruption (33%) was also diagnosed (AIS 4).



Figure 12. Damage to the 1993 Dodge Caravan in case GMP-006, with some parts removed. CDC: 01-FDEW-1; maximum crush: minor.

On hospital admission, the mother was experiencing abdominal pain and contractions approximately 3 minutes apart. Measurement of fetal heart rate indicated a non-reassuring tracing (“fetal distress”); a decision was made to deliver the baby by cesarean section within 3 hours of the crash. The 2.50 kg baby had mild respiratory distress syndrome due to premature birth, and required oxygen therapy during this initial time period. The baby was discharged 10 days after delivery, apparently doing well. No neonatal injuries resulted from the motor-vehicle crash.

**MINOR FRONTAL IMPACT TO BELT- AND AIRBAG-RESTRAINED RIGHT-FRONT PASSENGER WITH MINOR FETAL COMPLICATIONS (GMP-009).** A 1996 Toyota Camry was turning left when it struck the front of the case vehicle, a 1996 Chevrolet Lumina (Figure 13). The equivalent barrier speed is

estimated to have been approximately 16 kph. The 23-year-old female (170 cm, 88 kg), right-front passenger was 31 weeks pregnant. She was wearing the three-point belt and the airbag deployed. She sustained several AIS 1 injuries and was transported to the hospital complaining of contractions. The contractions stopped without intervention and she was discharged within 12 hours of the crash. Nine weeks after the crash, at a gestational age of 40 weeks, the patient delivered a healthy baby.



Figure 13. Damage to 1996 Chevrolet Lumina in case GMP-009. CDC: 12-FDEW-1; maximum crush: 14 cm.

**MINOR FRONTAL IMPACT TO BELT-RESTRAINED DRIVER WITH GOOD FETAL OUTCOME (GMP-016).** The pregnant driver of a 1994 Suzuki Swift attempted to turn left at an intersection, and her vehicle was struck in the front (Figure 14) by a 1990 Mercury Sable that was traveling in the opposite direction. The equivalent barrier speed is estimated to have been approximately 23 kph. The 26-year-old female (160 cm, 89 kg) driver was 23 weeks pregnant and was wearing the available three-point belt. She reportedly had her seat adjusted to a forward track position because of her short stature. She sustained several AIS 1 injuries. After the crash, the driver was transported to the hospital where the baby was monitored and found to be in good condition. Four months after the crash, at a gestational age of 39 weeks, she delivered a healthy baby.



Figure 14. Damage to 1994 Suzuki Swift in case GMP-016. CDC: 01-FDEW-1; maximum crush: 19 cm.

**MINOR FRONTAL IMPACT TO SHOULDER-BELT-RESTRAINED RIGHT-FRONT PASSENGER WITH MAJOR FETAL COMPLICATIONS (GMP-022).** The driver of a 1990 Chevrolet Beretta attempted to make a left turn in front of a 1990 Ford Tempo at an intersection. The delta V for the Tempo, which was struck in the center-left front as shown in Figure 15, is estimated to have been approximately 23 kph. The 18-year-old female (160 cm, 52 kg), right-front passenger was 28 weeks pregnant. She was wearing the automatic shoulder belt, but not the manual lap belt. The seat appeared to have been in the full-forward position, and she had her left foot on the instrument panel above the glove compartment. An unrestrained passenger in the right-rear seat loaded the seatback of the pregnant occupant.

It was reported that the pregnant occupant was holding her chest and breathing hard after the crash. Her foot and leg were still up on the dashboard, and she was unresponsive. She was pronounced dead on arrival at the hospital. Her most serious injuries were an AIS 5 heart laceration and AIS 4 lung contusions. An obstetrician was in the emergency department when the patient arrived and quickly performed a perimortem cesarean section. There was no placental abruption. The infant developed typical complications resulting from a premature birth, but showed no other problems of trauma. The infant was discharged 10 weeks later.



Figure 15. Damage to 1990 Ford Tempo in case GMP-022. CDC: 11-FYEW-2; maximum crush: 39 cm.

**MINOR FRONTAL IMPACT TO BELT- AND AIRBAG-RESTRAINED DRIVER WITH GOOD FETAL OUTCOME (GMP-027).** A 1995 Dodge Neon driven by a 38-week pregnant driver struck the rear of a 1991 Ford Escort that had stopped to make a left turn. Vehicle damage shown in Figure 16 was measured and the equivalent barrier speed is estimated to have been 13 kph. The 33-year-old (160 cm, 86 kg) driver was wearing the three-point belt and the frontal-impact airbag deployed. She sustained AIS 1 injuries to her upper extremities and abdomen. Approximately 3 weeks after the crash, the patient delivered a healthy baby by a planned cesarean section.



Figure 16. Damage to 1995 Dodge Neon in case GMP-027. CDC: 12-FDEW-1; maximum crush: 7 cm.

**MODERATE NEAR-SIDE IMPACT TO UNRESTRAINED RIGHT-FRONT PASSENGER WITH MATERNAL AND FETAL DEATH (GMP-002).** Because of icy road conditions, the driver of a 1989 Ford Tempo (Figure 17) lost control of the vehicle, which rotated into opposing traffic and was struck in the right-side door by a 1993 Ford Ranger. Severe intrusion into the right-passenger compartment resulted, and the delta V for the Tempo is estimated to have been approximately 42 kph. An 18-year-old female (160 cm, 54 kg) was the right-front passenger in the Tempo and was 28 weeks pregnant. She was not wearing the automatic shoulder belt or the manual lap belt. She sustained multiple injuries, including an AIS 4 liver laceration and an AIS 3 right distal femur fracture. She died from respiratory compromise when fluids from the femur fracture passed into the bloodstream and prevented normal lung function (fat embolism), complicated by severe hepatic trauma. The 28-week fetus died as a result of the trauma sustained by the mother. The fetus also sustained a fractured left humerus (AIS 2), probably due to loading by the side-door interior.



Figure 17. Damage to 1989 Ford Tempo in case GMP-002. CDC: 03-RYAW-4; maximum crush: 68 cm.

**MODERATE NEAR-SIDE IMPACT TO BELT-RESTRAINED DRIVER WITH GOOD FETAL OUTCOME (GMP-004).** A 1994 Ford Taurus driven by a woman who was 19.5 weeks pregnant was struck in the left-side front door (Figure 18) by a 1996

Ford Crown Victoria. An equivalent barrier speed of approximately 37 kph was estimated for the Taurus. The 28-year-old pregnant driver (173 cm, 59 kg) of the Taurus was wearing the three-point belt. During the left-side impact, she sustained AIS 2 pelvis fractures and an AIS 3 pubic symphysis separation. Initial diagnosis of the fetus was good. The infant was delivered vaginally about 4.5 months after the crash at 38.5 weeks gestational age. The baby was healthy with no problems, and the mother's pelvic injuries healed.



Figure 18. Damage to 1994 Ford Taurus in case GMP-004. CDC: 10-LPEW-3, maximum crush: 50 cm.

**MINOR NEAR-SIDE IMPACT TO UNRESTRAINED RIGHT-FRONT PASSENGER WITH MAJOR FETAL COMPLICATIONS (GMP-001).** A 1986 Chevrolet Cavalier with a 37-week pregnant right-front passenger was struck in the right-front fender (Figure 19) by the left rear of a 1993 Plymouth Sundance that was merging into the left lane. The estimated equivalent barrier speed of the side impact is 9 kph. The 21-year-old pregnant occupant (155 cm, 85 kg) was not wearing the available three-point belt, and reportedly had her seat in the full-forward position. She sustained AIS 1 contusions and abrasions to her head and knee.



Figure 19. Damage to 1986 Chevrolet Cavalier in case GMP-001. CDC: 03-RFEW-2; maximum crush: 10 cm.

The mother reported cessation of fetal movement after the impact. Spontaneous rupture of membranes occurred 1.5 hours after the crash, and the infant was born vaginally within 18 hours of the crash. In the first 2 days after being born, the infant experienced two episodes of apnea and seizure activity. A CT scan detected a left peridural / tentorial hemorrhage with a subdural hematoma (AIS 4). Given the uncomplicated birth process, it is likely that the infant's injuries were related to the mother's contact with the door armrest during the near-side impact. The infant was discharged after 4 days in stable condition.

**MINOR NEAR-SIDE IMPACT TO BELT- AND AIRBAG-RESTRAINED DRIVER WITH GOOD FETAL OUTCOME (GMP-011).** A 1995 International tractor-trailer pulled out in front of a 1992 Plymouth Grand Voyager. The 33-year-old female (157 cm, 69 kg) pregnant driver of the Voyager braked and steered to the right, but her vehicle was struck in the driver door and left-front fender by the tractor-trailer (Figure 20). The equivalent barrier speed of the Voyager for this side impact is estimated to have been about 16 kph, but this estimate may be low because of override of the truck on the Voyager. The driver, who was 22 weeks pregnant, reportedly had the seat in a midtrack position. She was wearing the three-point belt and the airbag deployed. She sustained AIS 2 head injuries in addition to multiple AIS 1 integumentary injuries. After the crash, she was transported to the hospital. The fetus was monitored and determined to be in good condition. Four months after the crash, at 40 weeks gestational age, the subject delivered a healthy infant.



Figure 20. Damage to 1992 Plymouth Grand Voyager in case GMP-011. CDC: 10-LYAW-3; maximum crush: 23 cm.

**MINOR REAR IMPACT TO BELT-RESTRAINED DRIVER WITH FETAL LOSS (GMP-021).** An Oldsmobile Cutlass traveling at low speed struck the rear of a 1990 Honda Civic driven by a 26-week pregnant driver. There was only about 1 cm of crush to the rear bumper of the Civic (Figure 21) and the delta V was calculated to be approximately 14 kph. The 36-year-old female (155 cm, 75 kg) driver of the Civic was wearing the three-point belt. The

pregnancy had been uncomplicated to date, with fetal heart tones and movements noted the day before the crash at a prenatal checkup. She did not sustain any injuries, but went to the hospital approximately 3 to 4 hours after the crash. At the emergency department, no fetal heart tones were found, and she was sent to labor and delivery. An ultrasound was conducted and it was determined that the fetus was dead. Autopsy of the 0.94 kg fetus did not indicate any anomaly other than the expected changes of a fetus that died in utero. There was no placental abruption or other specific trauma-related explanation for the fetal loss.



Figure 21.  
Damage to 1990  
Honda Civic in  
case GMP-021.  
CDC: 06-BDLW-  
1; maximum  
crush: 1 cm.

## DISCUSSION

In this study, impact severity and maternal injury are the factors most strongly associated with fetal outcome (Klinich et al.1999). Three cases presented in this paper particularly illustrate these associations. In case GMP-010, the 40-week three-point-belt-restrained pregnant driver sustained fetal loss and maternal injuries (ISS=29) in a severe frontal impact. The unrestrained mother and fetus both died in case GMP-002, a moderate near-side impact. Case GMP-026 involved a pregnant right-front passenger restrained by a three-point belt and airbag in a moderate frontal crash. She sustained moderate injuries, and her infant was diagnosed after birth with complications suspected to have resulted from the crash.

Most of the minor severity impacts presented (GMP-003, GMP-005, GMP-009, GMP-011, GMP-016, GMP-027) led to minimal maternal injury and uncomplicated fetal outcomes. The two remaining moderate frontal impacts presented (GMP-023 and GMP-025) also had good maternal and fetal outcomes to properly restrained occupants. In case GMP-004, the mother sustained several pelvic fractures in a moderate severity near-side impact, but the fetus experienced no problems. It is suspected that the small size of the fetus in this case (gestational age of 19.5 weeks) may have been a



significant factor in the lack of fetal injuries despite the compromised pelvic cavity.

Four of the cases presented are exceptions to the general finding that worse fetal outcomes are associated with increasing crash severity and maternal injury, illustrating that occasionally minor maternal injury can be associated with catastrophic fetal outcome. In three minor severity impacts, one frontal (GMP-006), one side (GMP-001), and one rear (GMP-021), the fetus had an adverse outcome although the crash was minor and the mother sustained minor or no injuries. In GMP-022, the fourth case, the mother died in a minor frontal impact, but the fetus was delivered prematurely and survived. The maternal death from internal bleeding from heart and spleen injuries in this case probably resulted from a combination of improperly using only the passive shoulder belt, irregular positioning with feet on the dash, and an unbelted rear passenger loading her seatback. It is also possible that the pregnancy may have contributed to maternal death, as the enlarged pregnant uterus directly contacts other abdominal organs such as the spleen.

Proper restraint of a three-point-belt with or without airbag deployment is associated with better fetal outcomes in low and moderate severity crashes (Klinich et al. 1999). In eleven of the cases presented in this paper, the pregnant occupant was wearing a three-point belt. In seven of these cases, an airbag also deployed. Seven of eleven properly restrained women had acceptable fetal outcomes (GMP-004, GMP-009, GMP-011, GMP-016, GMP-023, GMP-025, and GMP-027). All of these cases were minor or moderate in impact severity. In the four cases with adverse fetal outcomes to properly restrained women, one crash was a severe frontal (GMP-010), one was a moderate frontal (GMP-026), one was a minor frontal (GMP-006), and the fourth was a minor rear impact (GMP-021).

Five of the cases presented in this paper involved pregnant occupants who were improperly restrained and three of these resulted in adverse fetal outcome. As discussed previously, use of only a shoulder belt in case GMP-022 led to maternal death and premature delivery for a minor frontal crash. In the minor near-side impact of case GMP-001, the pregnant right-front passenger was unbelted, and her fetus was delivered early, 18 hours after the crash, with a head injury. Case GMP-002 was a moderate near-side impact to an unrestrained pregnant woman that resulted in maternal and fetal death. The other two cases with improper restraint (GMP-005 with airbag only and GMP-003 with no restraint) led to good fetal outcomes, but were frontal crashes of minor severity.

An interesting finding of this study is the effect of belt-restraint usage in near-side impacts. For the four near-side impacts presented, the two properly belt-restrained pregnant women (Case

GMP-004 and GM-011) had good fetal outcomes, while the unrestrained pregnant occupants of cases GMP-001 and GMP-002 had adverse fetal outcomes. This finding is somewhat unexpected, as belt restraints are generally not as effective at reducing injuries to occupants in near-side impacts [Thomas et al. 1987]. Most of the other near-side impacts in the database that were not described in this paper also have acceptable fetal outcomes for restrained occupants in near-side impacts.

Eight of the cases described in this paper involved airbag deployments. Two frontal crashes, one of minor severity (GMP-006) and the other of moderate severity (GMP-026), resulted in major complications for the fetus, but not in fetal death. The one airbag-only case included (GMP-005) had a good fetal outcome. The five other cases with airbag deployments had acceptable fetal outcomes. There were no cases where the airbag was considered to be the cause of an adverse fetal outcome or serious maternal injury.

Overall, proper restraint use has a positive effect on fetal outcome in low and moderate level crashes. Since crashes of this severity constitute over 95% of all crashes (based on analysis of NASS data on towaway crashes), these results support current recommendations that pregnant women should properly use three-point belts and should not disable the airbags [ACOG 1999]. Although the study found a strong association of poor fetal outcome with severe maternal injury and high crash severity, there are some notable exceptions where adverse fetal outcomes occurred in minor-severity crashes with little or no maternal injury. These exceptions support recommendations from the literature [Pearlman et al. 1997, 1990] that all pregnant occupants involved in crashes should seek medical treatment after the crash, regardless of the severity of maternal injury.

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(Presenter: Kathleen Klinich)

*Leonard Evans:* First, let me commend you on a very nice study most clearly and excellently delivered. It was so easy to follow. Easy though it was, I can't remember all the details, but there was one case where the outcome was bad, the delta V was low, there was a 3 point belt and an airbag and just casually looking at it, do you have some reason for excluding the possibility that it was the airbag that was the cause of the bad outcome?

*K. Klinich:* We actually think for that instance it was more the belt that induced the injury. There were uterine lacerations in that woman, they weren't directly underneath the belt, but they were on the posterior side of the uterus. We think it was from indirect loading by the belt because there were two lacerations which were about 2 inches apart which kind of indicated that the force was transmitted from the other side so we think for that case it was probably more the belt than the airbag.

*Carl Clark:* Additional protection in automobiles can be provided by preinflated airbags. It would be my recommendation that the system of having pregnant women ride in a car with preinflated and not deflated airbags would provide much better protection. This should be explored by somebody.

*K. Klinich:* We do have more airbag cases than have been previously reported with pregnant occupants and we were able to make some slight statistical conclusion that an airbag improves the outcome compared to a 3 point belt alone.

*C. Clark:* Do you understand what I mean by a preinflated airbag? As she drives out of the driveway, the airbag is preinflated. That ought to be explored.

*Stefan Duma:* Do you think your results or trends would change if you looked at the fetal morbidity as opposed to just mortality?

*K. Klinich:* We were counting adverse fetal outcome as pretty much anything with bad longterm consequences or death so our results do group that as an adverse consequence just because we did not have enough cases of fetal loss versus fetal injury.