

UMTRI-99-29

Investigations of Crashes Involving Pregnant Occupants

Final Report

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Submitted to:
General Motors Co. and National Highway Traffic Safety Administration
October 1999

Technical Report Documentation Page

1. Report No. UMTRI-99-29	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Investigations of Crashes Involving Pregnant Occupants		5. Report Date October 1999	6. Performing Organization Code
		8. Performing Organization Report No. UMTRI-99-29	
7. Author(s) K. D. Klinich, L. W. Schneider, J. L. Moore, M. D. Pearlman		10. Work Unit No. (TRAIS)	
9. Performing Organization Name and Address University of Michigan Transportation Research Institute 2901 Baxter Road, Ann Arbor, Michigan 48109		11. Contract or Grant No. 374843	
		13. Type of Report and Period Covered Final Report	
12. Sponsoring Agency Name and Address General Motors Corporation 30500 Mound Rd. Warren, MI 48090-9055		14. Sponsoring Agency Code	
15. Supplementary Notes The work covered by this report was financed by GM pursuant to an agreement between GM and the U.S. Department of Transportation.			
16. Abstract New estimates of annual fetal losses resulting from maternal involvement in crashes range from 300 to 3800. To further investigate the specific causes and circumstances surrounding these losses, forty-two investigations of real-world crashes involving pregnant occupants were conducted from a total of eighty-seven notifications of crashes involving pregnant occupants. Key features of the resulting database include a range of fetal outcomes, documentation of restraint use (including airbags), and engineering estimates of crash severity. The pregnant occupant was the driver in twenty-six cases, the right-front passenger in fourteen cases, and a rear-seat passenger in three cases. Eight occupants were unrestrained, eighteen were restrained by a three-point belt, thirteen were restrained by a three-point belt plus an airbag, two were restrained only by an airbag, one was restrained only by a shoulder belt, and one was restrained by a shoulder belt plus an airbag. The crashes are divided into three crash severity levels of severe (eight cases with a delta V greater than 30 mph), moderate (eight cases with a delta V between 15 and 30 mph), and minor (twenty-four cases with a delta V less than 15 mph). Twenty-seven crashes were frontal impacts, ten were side impacts, and six were rear impacts. Eight crashes resulted in fetal loss, eight crashes resulted in a placental abruption, a direct fetal injury, or extremely premature delivery without fetal loss, six crashes resulted in minor fetal complications, and twenty-one crashes resulted in good fetal outcomes. Results indicate that crash severity had the strongest negative effects on fetal outcome. Restraint use positively affected fetal outcome, providing support for proper use of a three-point belt during pregnancy. Risk estimates for properly restrained pregnant occupants show a much higher level of crash severity associated with a particular level of risk compared to the unrestrained occupants. Related to this is a positive relationship between maternal injury and fetal outcome, indicating that protection of the mother is important for protection of the fetus. Airbags also appear to have a positive effect and no negative effects of airbags were observed.			
16. Key Words trauma in pregnancy, crash investigations, fetal loss, airbag		17. Distribution Statement	
18. Security Classif. (of this report)	19. Security Classif. (of this page)	20. No. of Pages 146	21. Price

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EXECUTIVE SUMMARY

Firm statistics on fetal loss resulting from automotive trauma are not available because fetal death certificates do not record recent maternal involvement in crashes as a potential cause of death. Estimates of 1500-5000 fetal losses per year have been published in the literature. Several new estimates of the number of fetal losses were made using a variety of approaches based on crash statistics and pregnancy rates. The estimates range from 300 to 3800 fetal losses per year to women over 20 weeks gestation as a result of maternal involvement in a motor-vehicle crash.

This crash-investigation project was undertaken 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 second-generation pregnant crash dummy.

The new 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, and the database includes a significant number of pregnant occupants exposed to airbag deployments. A key strength of the database compared to the literature on motor-vehicle trauma during pregnancy is the inclusion of crash severity estimates based on vehicle damage measurements. In addition, the UMTRI database has detailed information on the fetal outcome that is missing from government (i.e., NASS) crash data.

Eighty-seven notifications of crashes involving pregnant occupants were received over the course of this project, from which forty-two investigations were conducted. Crashes were excluded from investigation if the case occupant was less than 20 weeks pregnant. Crashes were also not investigated if they involved multiple impacts, a vehicle rollover, or if the occupants did not agree to participate.

The forty-two investigated crashes were classified into twenty-seven major investigations and fifteen minor investigations. A minor investigation resulted for several reasons, including medical records not being available to confirm maternal and fetal outcome, and the vehicle not being available for inspection. Standard UMTRI crash investigation techniques were used for the major investigations. Information about the crash circumstances and conditions of the crash scene was determined, external vehicle and internal vehicle damage was measured and photographed, and detailed occupant and fetal data and injuries were obtained from medical records and subject interviews.

The pregnant occupant was the driver in twenty-six cases, a rear passenger in three cases, and the right-front passenger in fourteen cases. Eight occupants were unrestrained, eighteen were restrained by a three-point belt, thirteen were restrained by a three-point

belt plus an airbag, two were restrained only by an airbag, one was restrained only by a shoulder belt, and one was restrained by a shoulder belt plus an airbag. The crashes are divided into three crash severity levels of severe (eight cases), moderate (eleven cases), and minor (twenty-four cases). Twenty-seven crashes were frontal impacts, ten were side impacts, and six were rear impacts. Eight crashes resulted in fetal loss, eight crashes resulted in a placental abruption, a direct fetal injury, or extremely premature delivery without fetal loss, six crashes resulted in minor fetal complications, and twenty-one crashes resulted in good fetal outcomes.

Chi-square tests of independence were conducted to determine if different crash and occupant factors have a statistically significant effect on fetal outcome. Inspection of standardized residuals was used to examine the relationships between significant variables. For the data in this study, crash severity has the strongest effect on fetal outcome, with greater crash severities associated with poorer fetal outcomes. Maternal injury level also has a significant effect on fetal outcome, with worse fetal outcomes associated with increasing levels of injury to the mother. Maternal restraint use has a significant effect on fetal outcome, with proper restraint use (three-point belt or three-point belt plus airbag) associated with more positive fetal outcomes. Fetal outcome varies somewhat with both occupant seating position and gestational age, but the data do not indicate that poorer fetal outcome is associated with a particular seating position or gestational age. Impact direction and maternal stature and weight do not have a statistically significant effect on fetal outcome. When comparing outcomes to mothers restrained by a three-point belt versus a three-point belt and airbag, airbags appear to have a positive effect.

A risk analysis was conducted to estimate the relationship between crash severity and probability of adverse fetal outcome. The outcomes were divided into two categories: (1) good outcomes or minor complications, and (2) major complications or fetal losses. Using all of the cases in this study, the estimated crash severity for a 50% level of risk of adverse fetal outcome is 31.5 kph. Logistic regressions were also performed to compare the estimated risk curves for the properly restrained occupants (three-point belts or three-point belts plus airbags) and improperly restrained occupants (unrestrained, airbag only, shoulder belt only, with and without airbag.) The risk estimates for properly restrained pregnant occupants show a much higher level of crash severity associated with a particular level of risk compared to the unrestrained occupants. For a 20 kph crash severity level, the estimated risk of adverse fetal outcome for properly restrained pregnant occupants is less than 20%, while it is near 70% for unrestrained pregnant occupants.

Of thirty-one properly restrained occupants in the database, eight (25.8%) experienced fetal loss or major complications. Of twelve improperly restrained or unrestrained occupants, eight (66.7%) had fetal loss or major complications. These results clearly support the current recommendation that pregnant women properly wear the available three-point belt.

1.0 INTRODUCTION AND OBJECTIVES

Firm statistics on fetal loss resulting from automotive trauma are not available because fetal death certificates do not record recent maternal involvement in crashes as a potential cause of death. In addition, since miscarriage occurs in 10-20% of all pregnancies in the early part of pregnancy, only deaths to fetuses over 20 weeks gestational age are legally defined and recorded. However, based on the frequencies of pregnancies, involvement of pregnant women in motor vehicle crashes, and fetal loss rates due to trauma, it has been estimated that between 1500 and 5000 fetal losses occur each year in the United States as a result of maternal involvement in automotive crashes (Pearlman 1997). Additional adverse fetal outcomes undoubtedly occur as well, as uncounted numbers of children grow up with some type of disability as a result of trauma sustained in utero. Even if a fetus survives a crash event, complications arising from early emergency delivery of a premature fetus (such as low birth weight and neonatal respiratory distress syndrome) can lead to long-term negative consequences for the child.

Understanding how pregnant women and their fetuses are injured in crashes may help vehicle restraint designers to improve protection for pregnant occupants and their fetuses. The medical literature contains many case studies on pregnant women involved in automotive crashes. However, these cases do not have reliable estimates of the impact severity or detailed information about the vehicle damage, and they are generally biased toward negative outcomes. This limits their value to researchers and safety engineers who seek to improve automotive safety for pregnant women and their fetuses.

A primary automotive source of crashes and occupant injury information is the National Accident Sampling System (NASS) database developed by the National Highway Traffic Safety Administration. This database contains information on crashes investigated across the United States that are selected in a statistically representative manner. The records include injury and restraint usage information, vehicle damage data, and estimates of crash severity. While recent changes to the database include addition of the gestational age of pregnant crash victims, the data do not provide information on fetal outcome. This renders the current NASS database essentially useless for studies of fetal loss and injury in motor-vehicle crashes.

The purpose of this study was to conduct in-depth investigations of real-world crashes involving pregnant occupants. This study establishes the foundation of a database with accurate and quantitative crash information, along with detailed information on maternal and fetal injuries and outcome. The results will help identify safety issues and mechanisms of fetal injury and loss, and provide case data for validating the injury criteria proposed for the second-generation pregnant crash dummy.

2.0 BACKGROUND

2.1 Pregnant Anatomy

Figure 1 illustrates the general anatomy of a pregnant abdomen near term (Pritchard et al. 1985). The uterus is a muscular organ that grows in capacity from 5 mL to 5 to 10 L over the course of pregnancy. Its wall thickness at 7 months is about 2 cm, and at full term (40 weeks) it is about 1 cm. The uterus is attached to ligaments at the cervix which leads to the vagina, but is otherwise unattached in the abdominal cavity. As the uterus grows, it pushes other abdominal organs rearward and upward, and may rest against the anterior abdominal wall or the spine. The uterus is in close proximity to the lumbar and sacral spine. The size of the uterus depends more on the size of the fetus than the size of the mother. Since most women generally have babies who weigh 2.7 to 3.6 kg (6 to 8 pounds), uterine size is not expected to vary significantly with the stature or weight of the mother. This has been documented in a recent anthropometry study (Klinich et al. 1999).

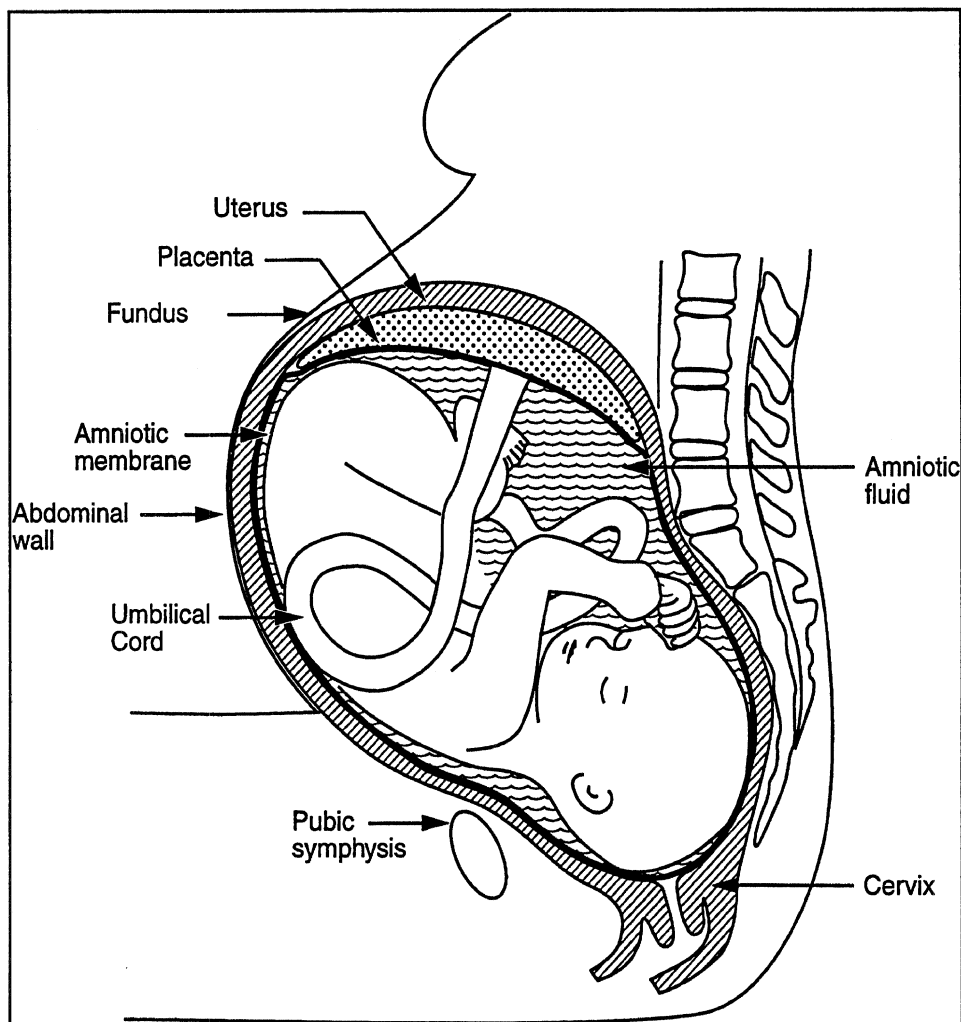


Figure 1. Anatomy of Pregnant Abdomen.

The placenta is a vascular organ within the uterus that exchanges oxygen, nutrients, and waste between the mother and fetus. Commonly called the afterbirth, it separates from the uterus and delivers spontaneously after the fetus is born. Eighty percent of placentas are located near the top (fundus) of the uterus by the third trimester. It is roughly circular in shape, and measures 2 to 2.5 cm in thickness in the last trimester of pregnancy. It covers approximately one-fourth of the internal surface area of the uterus throughout pregnancy. The placenta attaches to the uterus by microvilli, which are finger-like projections with diameters of about 50 μm . The microvilli grow into the superficial covering of the uterine wall called the decidual layer. The interface between the uterus and placenta is considered to be weaker than either of the two tissues, and is referred to as the uteroplacental interface (UPI).

The amniotic membrane lines the inner surfaces of the uterus and placenta and contains the fetus and the amniotic fluid. The umbilical cord runs from the placenta through the wall of the membrane to the fetus. As the fetus grows, the relative proportion of the uterine volume filled with amniotic fluid decreases to an estimated 10% at term. By the last trimester, the fetus is positioned with its head down in over 95% of pregnancies.

2.2 Overview of Injuries Unique to Pregnant Women

Injuries unique to pregnant occupants involved in motor-vehicle crashes include placental abruption, uterine rupture or laceration, and direct fetal injury, all of which can lead to fetal death. A brief description of these injuries and possible mechanisms follows.

Placental abruption is considered to be the most common cause of fetal loss in automotive crashes and can result from other mechanisms of trauma during pregnancy as well. It has been estimated to occur in 1 to 5% of minor severity crashes during pregnancy and in 20 to 50% of severe crashes during pregnancy (Pearlman 1997). The injury occurs when the placenta detaches from the uterine wall, disrupting the supply of oxygen and nutrients to the fetus. Partial abruptions can also occur, with the possibility of the pregnancy continuing successfully depending on the degree of placental separation from the uterus. The interface between the placenta and the uterus is considered to be weaker than either the uterus or the placenta, and therefore usually fails before either the uterus or placenta fails, by rupture or laceration, respectively.

Pearlman et al. (1990) have noted that the likelihood of placental abruption is independent of the placenta location on the uterus. This may imply that there are several mechanisms of placental abruption, with the particular cause depending on the placental location relative to the loading location and the nature of the loading. For example, some placental abruptions may result from high-velocity, low-mass airbag loading, or from compression between the mother's body and the steering wheel, belt, or instrument panel. Abruption may also result from acceleration differentials between the placenta and uterus. Thus, mechanisms of placental abruption may include inertial or direct loading that results in shear or tensile strains that exceed the UPI failure limits.

Uterine ruptures or lacerations are rare during pregnancy, occurring in less than 1% of pregnant trauma cases (Pearlman 1990). Injury to the uterus in automotive accidents

occurs almost exclusively during pregnancy (compared to any other time) because it is much larger, extends outside the pelvic cavity, and is filled with fluid. While uterine rupture is very rare, the likelihood of fetal death with such an injury is near 100%.

Uterine injury is often reported in the literature as resulting from direct loading by the seat belt. While this may occur, it can also occur to unbelted women whose abdomens are directly loaded by the steering wheel or instrument panel. Some cases report uterine damage directly beneath the area of seatbelt loading (Matthews 1975). Other cases report the site of uterine rupture as being opposite the site of loading, suggesting a “contrecoup” type of injury mechanism (Van Enk and Van Swam 1994).

Direct fetal injury (DFI) is also quite rare, occurring in less than 1% of automotive crashes involving pregnant occupants (Pearlman 1990). In the first 3 months of pregnancy, the uterus is still completely surrounded by the pelvic bones and is considered a pelvic organ. After the first 3 months, the uterus protrudes out from the abdomen, but the structure of the pregnant abdomen protects the fetus by encasing it in amniotic fluid that acts as a shock absorber to isolate the fetus. The fetus sometimes sustains injury from direct loading of the abdomen when pelvic fractures or uterine rupture compromise the protective cavity. The most frequently injured fetal body region is the head, because it is the largest part of the fetal body and offers the “biggest target.” It is thought that skull fracture most often occurs when the fetal head is loaded against the bony structures of the maternal pelvis or spine by a belt, steering wheel, or instrument panel.

Some pregnant automotive crash victims suffer negative pregnancy complications whether or not they sustain any placenta, uterus, or direct fetal injuries. One common complication is premature delivery, in which the infant often has a low birth weight and can suffer from neonatal respiratory distress syndrome because the lungs are not fully developed. Both of these factors can lead to health problems and disabilities throughout the child’s life.

Even if a fetus is very close to full term, maternal involvement in a crash can lead to an emergency cesarean delivery, which poses higher risks to the mother and neonate. Contractions often begin after an accident, sometimes requiring drug intervention to prevent early delivery. Crashes involving pregnant occupants occasionally result in stillborn births without any visible injury responsible for the loss.

2.3 Literature Review

2.3.1 Clinical Studies

Many of the estimates on the frequencies of adverse fetal outcomes resulting from motor-vehicle crashes come from clinical studies of pregnant women admitted for emergency treatment. Death certificates are also reviewed to gain insight into the causes and frequencies of maternal and fetal deaths. These studies also reviewed factors indicative of injuries such as placental abruption, which does not always exhibit obvious symptoms. A review of the literature on publications of this nature follows.

Dahmus and Sibai (1993) studied hospital records of 233 pregnant trauma victims to determine clinical signs of placental abruption or fetal distress and to determine how frequently they occur. Their inclusion criteria were pregnant women of at least 20 weeks gestational age admitted to one hospital over a 3-year period. They included only cases of noncatastrophic blunt abdominal trauma plus all noncatastrophic motor vehicle trauma cases whether or not the abdomen was directly injured. Twenty-six percent of the cases were motor-vehicle crash victims. They determined that placental abruption and fetal distress occur at rates of 3% and 2%, respectively, after blunt abdominal trauma.

Esposito et al. (1991) conducted an analysis of seventy-nine pregnant patients admitted to one trauma center over a 9-year period. A control group of nonpregnant trauma victims of similar age and injury severity score were used for a comparison. Of the pregnant patients, 75% were automobile occupants, and 35% had injury severity scores (ISS) greater than 16. Mortality rates were near 10% for both groups. Fetal loss rate was 34%. All gestational ages were included.

Hoff et al. (1991) analyzed data on seventy-three pregnant trauma victims treated in four level-1 trauma centers in Pennsylvania. About 70% of the patients were involved in motor-vehicle crashes, and all gestational ages were included. Nine fetal losses occurred in their sample, with eight of these in motor-vehicle crashes. Three of the losses were to restrained drivers and one was to a restrained passenger, although the type of occupant restraint is not reported. The remaining motor-vehicle crash fetal losses were to unrestrained women. The researchers studied fetal loss as a function of twenty-one different maternal characteristics. The likelihood of fetal loss was correlated with increasing ISS, increasing face and abdominal abbreviated injury score (AIS), increasing fluid requirements, maternal acidosis, and maternal hypoxia.

Kissinger et al. (1991) reviewed the records of ninety-three injured pregnant women admitted to three level-1 trauma centers over 5 years to assess parameters that might predict fetal outcome. All gestational ages were included. Approximately 26% of the mothers were admitted to intensive care units, and the study had a 15% fetal loss rate. Fetal death rates were above average when the mother experienced uteroplacental injury, shock, pelvic fracture, severe head injury, or hypoxia. They did not find evidence to indicate that measurable fetal heart rate was predictive of fetal outcome.

Pearlman et al. (1990) analyzed the outcomes of eighty-five women who suffered from trauma during pregnancy (after 12 weeks gestation) and compared results (matching gestational age) to the outcomes of pregnant women who did not experience trauma. Sixty percent of the trauma cases involved motor-vehicle crash victims, and two of the pregnant trauma victims sustained severe injuries. Those who experienced trauma were more likely to have fetomaternal transfusion. For the trauma group, immediate adverse outcomes did not depend on the severity of maternal injuries. In this study, they found a 6% rate of placental abruption and a 1% fetal death rate. Barring the 9% of trauma cases with immediate adverse outcomes, there was no difference in fetal outcome between the trauma group and the control group.

Williams et al. (1990) present a review of eighty-three cases of pregnant women who experienced potential abdominal trauma after the 25th week of pregnancy. Thirty-five percent of patients were involved in motor-vehicle crashes. Adverse outcomes included 2.4% with placental abruption and 1% with fetal loss.

Goodwin and Breen (1989) analyzed 205 cases of noncatastrophic trauma that occurred during the second half of pregnancy (> 18 weeks). Cases from one hospital over a period of 21 months were examined. Twenty-seven percent involved motor-vehicle crashes. Complications resulting from trauma occurred in 8.8% of the cases. Cases with negative outcomes included 2.4% with placental abruption and 0.98% with fetal loss.

Timberlake and McSwain (1989) reviewed all pregnant trauma victims treated at their hospital over a 10-year period. Twenty-five subjects were included in the study; nine were injured in motor-vehicle accidents. Of the nine motor-vehicle accident cases, three of the fetuses died in utero. One case involved a ruptured uterus; the other cases do not list the specific fetal injuries. Details about the crashes and restraints are not provided.

Rothenberger et al. (1978) examined 103 cases of blunt trauma to pregnant women. They included all gestational ages, all pregnant women hospitalized because of trauma within a 6-year period, and all fetal/neonatal deaths after blunt maternal injury over the preceding 14 years. Just over half of the cases involved automotive occupants, and 20% of the mothers were seriously injured. They had a fetal loss rate of 14.6% and placental abruption rate of 8.5%. The authors compared maternal and fetal outcome to the severity of the mother's injuries. Fetal loss generally occurred in conjunction with maternal death, placental injury, uterine injury, direct fetal injury, and maternal hemorrhagic shock.

Elliot (1966) presents a study of thirty-nine pregnant women injured in traffic accidents over a 12-year period. The study includes pedestrians and motorcycle riders in addition to vehicle occupants. All of the mothers were considered to be seriously injured, and there was a 38.5% fetal loss rate, and 10.2% rate of placental abruption. They found uncontrolled bleeding to be the leading cause of maternal death. Restraint use was not reported. Among the women who survived, major orthopedic injuries were common, particularly pelvic fractures. Of the cases studied, only one case of placental abruption occurred, and no uterine rupture occurred.

Fort and Harlin (1970) examined the records of all pregnant women admitted to their hospital over 3 years who experienced minor trauma to the abdomen, and two cases of catastrophic trauma. They had a 1% fetal loss rate in their study of 212 women.

2.3.2 Epidemiological Studies

Other researchers interested in the frequency of trauma to pregnant women resulting from motor-vehicle crashes have focused more on the automotive perspective. Several such studies are presented below.

In the late 1960s, Crosby and Costiloe reviewed cases of 441 pregnant crash victims identified from California accident reports. When comparing lap-belted and unbelted

pregnant occupants, they found that the leading cause of fetal death was maternal death. Mainly for this reason, they concluded that lap belts are preferable to no restraint. When the mother survived, placental abruption was the leading cause of fetal death.

Pepperell et al. (1977) studied motor-vehicle crashes involving pregnant women occurring in a particular state of Australia over a 2-year period. They found five cases of maternal death and twenty-seven cases of fetal death. For each case, they document gestational age, impact direction, occupant position, restraint use, time of fetal death relative to the crash, and maternal, placental, and fetal injury. Severe maternal injury only occurred to unrestrained occupants. The authors believe that fetal death resulted from seat-belt loading in half of the cases. Placental abruption occurred in eighteen cases, twelve of them involving restrained occupants. Two of the three cases of uterine rupture involved belt-restrained women. They do not report cases in which the fetus survived. Herbert and Henderson (1977) refute the statements of Pepperell et al. because there was no control group. Their analysis of the Pepperell et al. data actually suggests that seat belts are beneficial to the fetus and mother in minor and moderate crashes, and are neither particularly helpful nor harmful in severe crashes. Lane (1977) also disagrees with the analysis by Pepperell et al. The author points out that Pepperell does not specify the type of belt restraint, or whether it was properly positioned. Lane points out that belt use changes injury patterns; Pepperell's data show that lack of restraint led to five maternal deaths and 12 fetal losses, while use of belt restraints led to 14 fetal losses.

Renault researchers conducted a general study on seat-belt use, with a particular section devoted to pregnant occupants (Hartemann et al. 1984). Their 10-year accident investigation file included forty-nine pregnant women involved in motor-vehicle crashes. None of the belt-restrained women sustained serious injuries, three of the unbelted women and their fetuses died, and four unbelted women sustained serious injuries. No cases of uterine rupture or placental abruption were documented.

Agran et al. (1986) studied all nine reported cases of fetal death secondary to maternal involvement in a motor-vehicle collision over a 3-year period in Orange County, CA. Placental abruption was documented in every case. In half of the cases, the mother's other injuries were minor, and signs of fetal distress were not always apparent at the time of the initial medical evaluation. All of the pregnant occupants were unbelted, and most were drivers who are suspected to have contacted the steering wheel with their abdomen. The authors recommend fetal monitoring after any crash with a pregnant occupant, regardless of how minor the mother's injuries appear to be.

Lane (1989) examined the circumstances and outcomes of thirteen third-trimester fetal deaths due to trauma reported over a 4-year period in Ontario. Summary statistics of the impact direction, restraint use, occupant position, and fetal outcome are given, but the details of each case are not presented. Placental injuries occurred in nine cases, and uterine rupture in four. Five of the fetuses directly experienced major trauma, usually to the head. One other fetus sustained a minor injury in utero. In eight of the cases, the mothers sustained either no injury or minor injury.

Fildes et al. (1992) reviewed ninety-five cases of maternal death over a 3-year period. Death from trauma occurred in 46.3% of the cases. Of these, 20.5% resulted from motor-vehicle crashes.

Wolf et al. (1993) searched the Washington state police and birth/death records to find approximately 2600 cases of pregnant women (greater than 20 weeks gestation) involved in crashes over an 8-year period. Unrestrained pregnant women drivers involved in crashes were 1.9 times more likely to have a low birth weight baby, and 2.3 times more likely to give birth within 48 hours after the crash as compared to restrained pregnant drivers.

Aitokallio-Tallberg and Halmesmaki (1997) analyzed thirty-five pregnant women involved in crashes. Fifteen cases were frontal impacts, thirteen were side impacts, five were multiple impacts, and two were cyclists. Twenty-eight of the pregnant occupants wore three-point belts. They found more complications for the side impact cases compared to the frontal impact cases. In the five crashes estimated to be most severe, fetal loss occurred as a result of placental abruption.

2.3.3 Case Studies

In addition to studies of multiple cases involving motor-vehicle trauma to pregnant occupants, researchers often publish case studies describing a single crash. Table A.1 in the Appendix provides information taken from the medical and automotive safety literature on 100 automotive crashes involving pregnant occupants. The main criteria for inclusion in this review were availability of information on restraint usage by the pregnant occupant and the pregnant occupant being at least 20 weeks pregnant. Cases summarized as part of epidemiological studies are included if enough information is given about each individual crash. Since most medical case studies focus on the injuries and treatment and not the crash event, information regarding the impact direction is often unavailable. In addition, the estimate of the crash severity is not based on physical crush measurements but derived from the occupant's or physicians' estimates. Cases are usually reported in the literature because they involve an unusual or serious injury and are not intended to be representative of situations experienced by most pregnant occupants.

For the cases in Table A.1, 54% involved pregnant drivers and the remainder were passengers, with the exact location often unspecified. The data contain no cases of pregnant women restrained only by airbags, and only four cases of women restrained by a three-point belt and an airbag. In eleven cases, the pregnant occupant was wearing a three-point belt. The pregnant occupant was described as "restrained" in nineteen cases without further specification. Improperly positioned belts were noted in four cases, and lap belt only was used in seven cases. The remaining fifty-five cases involved unrestrained pregnant occupants.

The impact direction was frontal in sixty-two cases and side in twenty-three cases. Rollovers, rear, multiple, and unknown impacts make up the remaining 15% of the cases. Most of the time, impact severity was unknown (69%). Impact severity was estimated as severe in twenty cases, moderate in five, and minor in six cases.

The gestational ages of the pregnant occupants described in these cases from the literature were skewed towards the later weeks of pregnancy. Ten cases were from 20-23 weeks, sixteen cases from 24-27 weeks, twenty-one cases from 28-31 weeks, twenty-one from 32-35 weeks, thirty-one at least 36 weeks, and one unknown gestational age. Fifteen of the mothers sustained no injury, fifty-six suffered minor injuries, twenty-three had moderate injuries, and six sustained major injuries. Maternal injuries led to maternal and fetal death in seven cases.

Of these 100 cases, only three had good fetal outcomes: one with the pregnant occupant restrained without further specification and two others where the pregnant occupant was restrained by an airbag and belt. Five cases had minor complications that include contractions, premature delivery, and/or emergency cesarean delivery. Four of these mothers were unrestrained, and one was restrained by a belt and airbag.

In twelve cases, the fetus lived but had major complications, including direct fetal injury, partial placental abruptions, and/or extremely premature delivery. Seven of these pregnant occupants were unbelted, two were wearing only a lap belt, one wore a three-point belt, and two were described as restrained without further detail.

The fetus died in eighty of these cases. In twenty-eight cases, the fetus sustained a direct fetal injury. One of these also involved a uterine injury, five had both uterus and placenta injuries, and fifteen also had placenta injuries. Seven cases resulted in a fatal direct fetal injury only. In the fifty-two other fetal loss cases without direct fetal injury, six were from an unknown cause, seven from uterine rupture only, eight from placental and uterine injury, one from an amniotic sac rupture, and thirty cases with only a placenta injury.

In the eighty cases with fetal loss, over half the losses (n=44) were to unrestrained mothers. Four cases involved improper belt use, and five occupants were restrained by only a lap belt. Sixteen pregnant occupants with fetal losses were restrained without further description, while ten were wearing a three-point belt, and one was restrained by a belt and airbag.

3.0 CRASH INVESTIGATION METHODS

Several different methods were used to identify crashes involving pregnant occupants. Medical staff of trauma centers were contacted to request that they notify UMTRI crash investigators of pregnant crash victims admitted for treatment after obtaining permission from the patient. Several articles were placed in various medical publications requesting assistance in identifying potential cases. In addition, local law enforcement agencies were asked for help, and police crash reports in the local area were checked on a regular basis. Prior to participating in the study¹, each pregnant occupant was asked to read and sign the consent forms provided in Appendix B.

A total of eighty-seven notifications of crashes involving pregnant occupants was received over the course of this project, from which forty-two investigations were conducted as shown in Table 1. Crashes were excluded from investigation if the pregnant occupant was less than 20 weeks pregnant. This gestational age limit was established because approximately 10-20% of pregnant women experience fetal loss prior to 20 weeks, and correlations of fetal loss with a motor-vehicle crash this early in pregnancy would be questionable. Crashes were also not investigated if they involved multiple impacts or a rollover of the case vehicle, which make determining occupant contact points and occupant kinematics very difficult. The third reason for excluding a crash was that the occupants did not agree to participate. Twenty-nine crashes were excluded for this reason.

Table 1
Summary of Case Classifications

87	Total Notifications		
42	Investigated		
	27	Major	
	15	Minor	
		9	vehicle could not be inspected
		5	complete medical records not available
1	no vehicle damage or maternal injuries		
45	Excluded		
	10	occupant less than 20 weeks pregnant	
	6	crash involved rollover or multiple impacts	
	29	occupants did not agree to participate	

¹ The rights, welfare, and informed consent of the volunteer subjects who participated in this study were observed under guidelines established by the U.S. Department of Health and Human Services on Protection of Human Subjects and accomplished under medical research design protocol standards approved by the Committee to Review Grants for Clinical Research and Investigation Involving Human Beings, Medical School, The University of Michigan.

The forty-two investigated crashes were classified into twenty-seven major investigations and fifteen minor investigations. A minor investigation resulted for several reasons, including medical records not being available to confirm maternal and fetal outcome, and the vehicle not being available for inspection, usually because it had already been repaired. Estimates of the crash severity in these instances were based on investigator evaluation of the reported or photographed damage, rather than calculations based on crush measurements.

Standard UMTRI crash investigation techniques were used in this study for the major investigations. Each case was documented using the UMIVOR variable set, Version 5, which provides for coding information about the crash situation and conditions of the crash scene, external vehicle damage, internal vehicle damage, and occupant data and injuries. Each case also was documented in a narrative that describes the crash event and crash scene, vehicle exterior and interior damage, hypothesized occupant kinematics and contacts with the vehicle interior, and resulting occupant injuries. Color 35-mm slides of the crash scene and exterior and interior damage of the case vehicle were also used to record each major investigation.

Details regarding the crash were obtained from police reports and interviews with the crash victims. The external damage was measured and photographed; crush measurements were input to the WinSMASH program to estimate impact severity. Internal damage was also measured and photographed, with particular attention paid to evidence of occupant contact with interior components and use of belt restraints.

The case occupant was interviewed to obtain information regarding her physical characteristics, injuries sustained, and actions taken prior to and during the crash. Detailed injury information and the medical history of the case occupant were obtained from medical records.

A follow-up interview with the case occupant was also conducted after the baby was born to confirm the information on fetal outcome. If complications occurred as a result of the crash, the neonate's medical records were also reviewed.

In a few cases, the pregnant occupant was photographed and measured in her vehicle within a few days of the crash if she had not yet given birth. Distances between the pregnant abdomen and interior vehicle components were recorded.

4.0 RESULTS

Information about the crashes investigated in this study is presented four different ways. Section 4.1 contains a table listing the pertinent factors for all major and minor investigations. Section 4.2 contains graphs showing the distributions of different factors such as occupant position and impact severity. Section 4.3 provides brief narratives of all the cases, grouped by impact direction and severity, plus a summary that compares the characteristics of the crashes within each direction/severity grouping. Appendix C contains one-page summaries of all cases, which include scene diagrams, photos of vehicle damage, occupant, impact, and vehicle information, and descriptions of the neonatal outcome and maternal injuries.

4.1 Summary of UMTRI Pregnancy Crash Investigations

Table 2 summarizes information for the forty-two major and minor crash investigations conducted in this study. The cases are grouped by impact direction, impact severity, and gestational age, rather than by case number. Case numbers of 200 and above are assigned to minor investigations. Impact severity is categorized as minor (0-15 mph), moderate (15-30 mph), or severe (30+ mph). Gestational age is grouped into 4-week intervals to allow for comparisons based on anatomical differences. The maternal injuries rating is based on ISS score, excluding injuries to the placenta or uterus. A minor rating is assigned to ISS <10, a moderate rating to ISS scores from 10 to 20, and a major rating to ISS scores greater than 20. As noted in the footnote, case 207 involved two pregnant occupants, designated by case numbers 207A and 207B. For tabulation purposes, this crash is counted twice for a total number of pregnant occupant cases of forty-three.

Table 2
Summary of Major and Minor Crash Investigations Involving Pregnant Occupants

Case #	Impact Direction	Impact Severity	Occupant Position	Occupant Restraint	Gestational Age (wk)	Maternal Injuries	Fetal Outcome
GMP-214	front	severe	driver	shoulder belt & airbag	36+	moderate	fetal loss, placental abruption
GMP-013	front	severe	left rear	none	28-31	moderate	fetal hydrocephalus from intraventricular hemorrhage, probably from crash
GMP-206	front	severe	driver	3-pt belt	28-31	minor	fetal loss
GMP-010	front	severe	driver	3-pt belt	36+	moderate	fetal loss, placental abruption
GMP-203	front	moderate	right front	3-pt belt	36+	minor	delivery within 48 hours
GMP-208	front	moderate	driver	3-pt belt	24-27	none	fetal loss, placental abruption, early delivery
GMP-216	front	moderate	driver	3-pt belt & airbag	24-27	moderate	premature birth, respiratory distress, placental abruption, apnea, intraventricular hemorrhage
GMP-026	front	moderate	right front	3-pt belt & airbag	28-31	moderate	fetal head injury, probably from crash
GMP-008	front	moderate	right front	3-pt belt	36+	none	contractions stopped without intervention
GMP-023	front	moderate	right front	3-pt belt & airbag	36+	minor	no problems
GMP-025	front	moderate	driver	3-pt belt & airbag	36+	minor	no problems
GMP-211	front	moderate	driver	3-pt belt & airbag	36+	minor	no problems
GMP-005	front	minor	driver	airbag	20-23	minor	no problems
GMP-016	front	minor	driver	3-pt belt	20-23	minor	no problems
GMP-018	front	minor	driver	none	20-23	minor	no problems
GMP-014	front	minor	driver	3-pt belt & airbag	24-27	minor	no problems
GMP-015	front	minor	driver	3-pt belt & airbag	24-27	minor	no problems
GMP-019	front	minor	driver	3-pt belt	24-27	none	no problems
GMP-020	front	minor	driver	3-pt belt	24-27	minor	no problems
GMP-215	front	minor	rear pass	3-pt belt	24-27	none	no problems
GMP-009	front	minor	right front	3-pt belt & airbag	28-31	minor	contractions stopped without intervention
GMP-022	front	minor	right front	shoulder belt	28-31	major (fatal)	premature birth, fetal respiratory distress
GMP-006	front	minor	driver	3-pt belt & airbag	32-35	minor	uterine lacerations, placental abruption, fetal respiratory distress, early delivery

Table 2
Summary of Major and Minor Crash Investigations Involving Pregnant Occupants

Case #	Impact Direction	Impact Severity	Occupant Position	Occupant Restraint	Gestational Age (wk)	Maternal Injuries	Fetal Outcome
GMP-027	front	minor	driver	3-pt belt & airbag	36+	minor	no problems
GMP-202	front	minor	driver	airbag	36+	minor	contractions stopped at hospital
GMP-204	front	minor	right front	3-pt belt & airbag	36+	minor	contractions stopped at hospital
GMP-003	front	minor	right front	none	36+	minor	no problems
GMP-207A*	rear	severe	right front	none	32-35	minor	placental abruption, early delivery
GMP-207B*	rear	severe	rear pass	none	32-35	minor	placental abruption, early delivery, possible fetal head injury
GMP-017	rear	minor	driver	3-pt belt	24-27	minor	no problems
GMP-021	rear	minor	driver	3-pt belt	24-27	none	fetal loss
GMP-213	rear	minor	driver	3-pt belt	32-35	none	no problems
GMP-210	rear	minor	driver	3-pt belt	36+	minor	contractions stopped without intervention
GMP-205	side	severe	driver	none	20-23	major (fatal)	fetal loss (twins)
GMP-212	side	severe	right front	3-pt belt	24-27	major (fatal)	fetal loss
GMP-004	side	moderate	driver	3-pt belt	20-23	moderate	no problems
GMP-024	side	moderate	right front	airbag	20-23	minor	no problems
GMP-002	side	moderate	right front	none	28-31	major (fatal)	fetal loss, fetal arm fracture
GMP-011	side	minor	driver	3-pt belt & airbag	20-23	minor	no problems
GMP-012	side	minor	right front	3-pt belt	28-31	none	no problems
GMP-007	side	minor	driver	3-pt belt	32-35	minor	no problems
GMP-001	side	minor	right front	none	36+	minor	early delivery, fetal head injury
GMP-209	side	minor	driver	3-pt belt	36+	none	no problems

* This crash involved two pregnant occupants in one vehicle.

4.2 Overview of Database

Figure 2 shows the distribution of crashes in this database by impact direction. Over 60% of the cases (n=27) involved a frontal impact as the primary crash event. The side impact cases (n=10) are biased towards near-side impacts, with only two of the cases involving far-side impacts. The impact direction was to the rear in the six remaining cases.

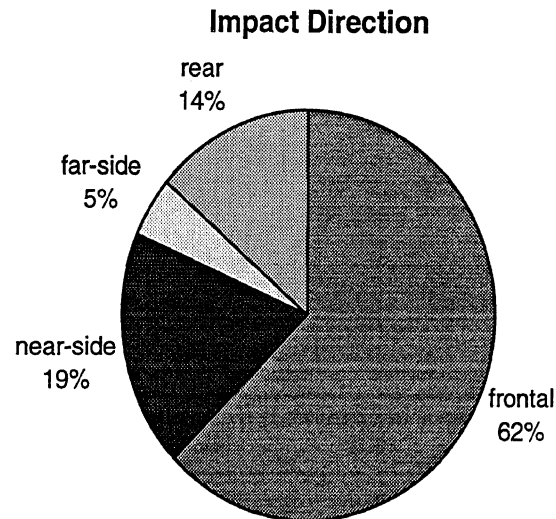


Figure 2. Distribution of impact direction.

Impact severity for the investigated crashes is shown in Figure 3. Over half of the cases were considered minor, with crash severities less than 24 kph in twenty-four cases. Almost 20% of the crashes were categorized as severe (n=8), with severities greater than 48 kph. The remaining eleven cases were considered moderate, with severities between 24 and 48 kph.

Figure 4 shows the distribution of pregnant occupant position in the crashes of this study. Over half were drivers (n=26), and only three case occupants were in the rear seat. The remaining fourteen pregnant women occupied the right-front seat.

Restraint use of the pregnant subjects in this study is illustrated in Figure 5. About 20% of the pregnant occupants (n=8) were unrestrained (no belts or airbag), while 72% were wearing a three-point belt (n=31). Of those wearing three-point belts, about 40% were also restrained by a deploying airbag (n=13). Four subjects were considered improperly restrained because they did not follow the recommended method of wearing the three-point belt. One used a shoulder belt only, one used a shoulder belt and airbag, and two used only the airbag restraint.

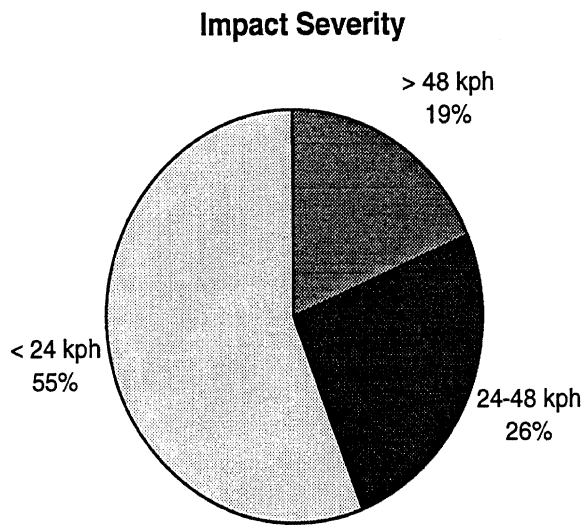


Figure 3. Distribution of impact severity.

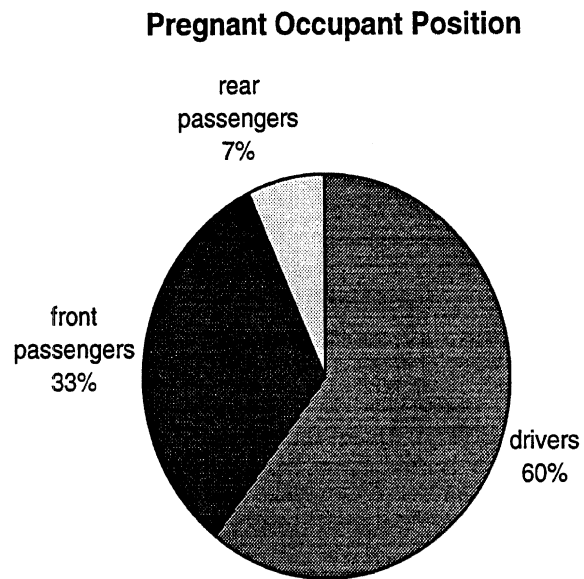


Figure 4. Distribution of pregnant occupant position.

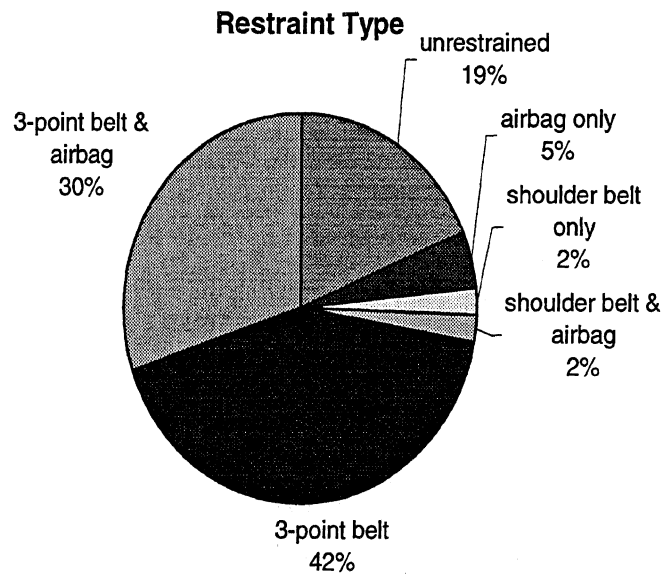


Figure 5. Distribution of pregnant occupant restraint type.

Figure 6 shows the distribution of the maternal injuries (excluding placenta or uterus injuries) in this study. Almost 80% of the pregnant occupants sustained no injuries (n=8) or minor injuries (n=25). Fourteen percent sustained moderate injuries (n=6), while 2% (one occupant) sustained major injuries. Three pregnant occupants died as a result of their injuries.

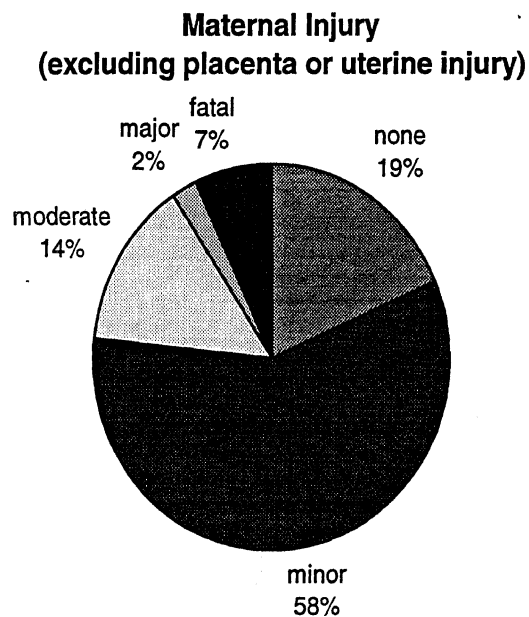


Figure 6. Distribution of maternal injury severity.

Figure 7 shows the distribution of gestational age for the sample of pregnant occupants involved in crashes in this study. Fourteen pregnant occupants in these crashes were in their final month of pregnancy, and twenty-six occupants were beyond 28 weeks.

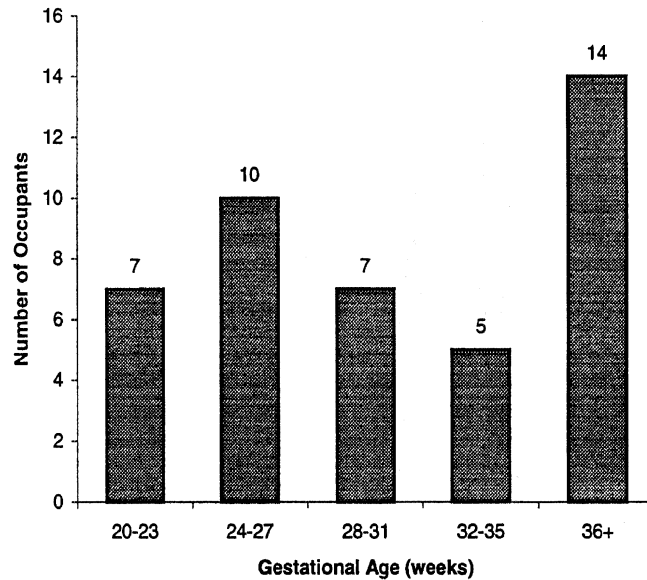


Figure 7. Distribution of gestational age.

Figures 8 and 9 show the distributions of pregnant occupant weight and stature. The distribution of weight follows the typical skewed distribution expected in a random population. The stature distribution is roughly normally distributed as is the general population. Figure 10 shows a plot of weight vs. stature for the women in this database. The typical increase in weight with height is not apparent, and may partly result from the range of gestational ages in this database.

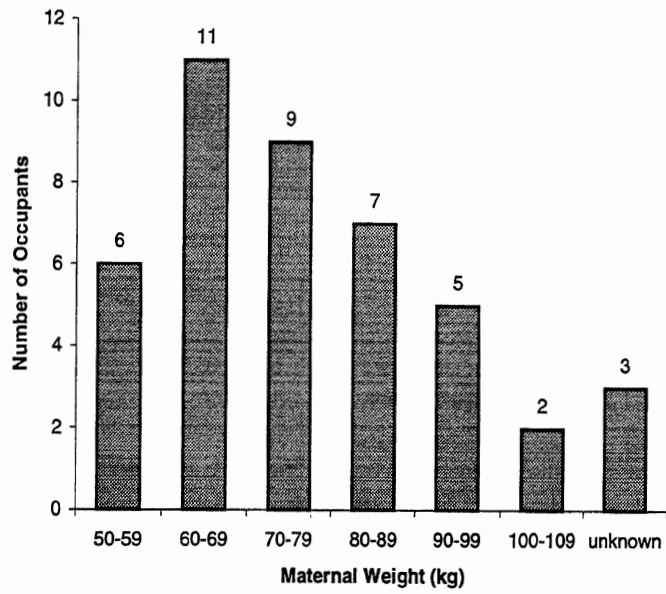


Figure 8. Distribution of maternal weight.

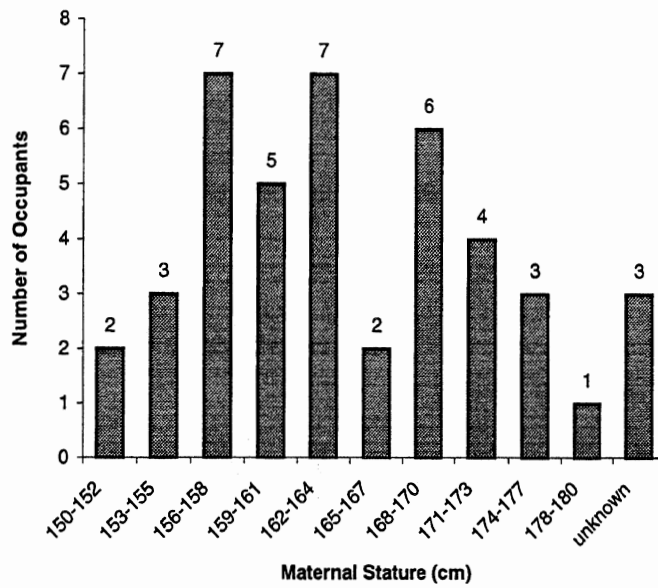


Figure 9. Distribution of maternal stature.

Maternal Weight vs. Stature

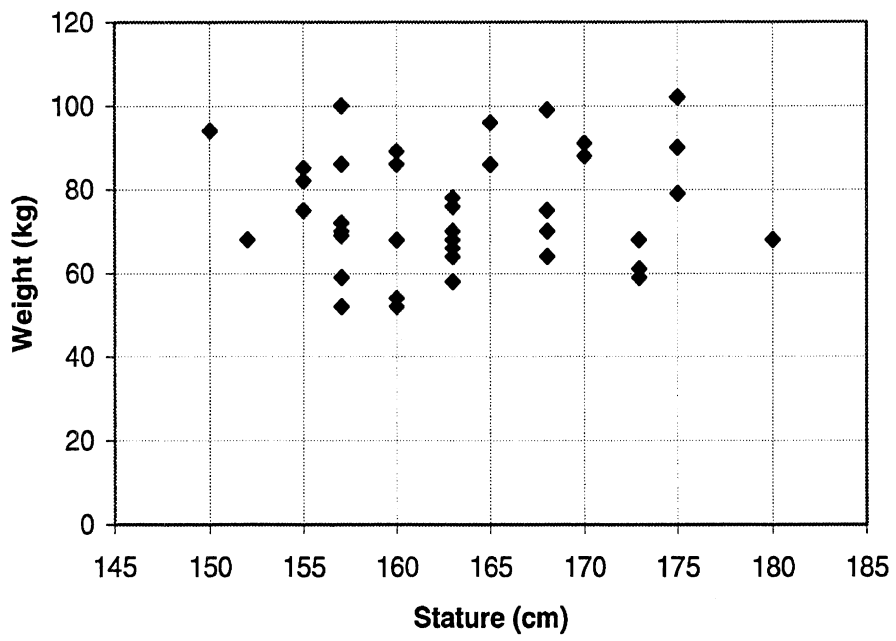


Figure 10. Maternal weight vs. stature.

4.3 Summaries and Case Narratives

4.3.1 Summary of Severe Frontal Impacts

Four cases involved frontal impacts with crash severities greater than 48 kph. The fetus died in three cases, and sustained a trauma-induced hydrocephaly in the fourth case. Two of the fetal losses occurred to drivers wearing three-point belts; one of these mothers sustained only minor injuries, while the other received extensive injuries, primarily to the lower extremities. The third fetal loss occurred to a driver who was restrained by the shoulder belt and airbag, but not the manual lap belt. Her specific injuries are not known but are believed to be of moderate severity. The nonfatal fetal injury case involved an unrestrained rear-seat passenger who was lying in a prone position at the time of the crash; the mother sustained moderate levels of injury. Placental abruption is suspected to be the cause of fetal death in all three fetal loss cases. Two of the fetuses in these severe crashes, including the survivor, were approximately 28 weeks gestational age, while the other two were 40 and ~36 weeks.

4.3.2 Case Narratives for Severe Frontal Impacts

GMP-010

A 1992 Saturn SL2, driven by a 30-year-old pregnant female, was involved in an extremely severe head-on crash with a 1987 Ford Mustang. For an unknown reason, the Saturn crossed the centerline and struck the Mustang in an offset mode. The direct damage began at the left-front bumper corner of the Saturn and extended 60 cm across the front, resulting in 38% vehicle overlap. The maximum crush to the left-front bumper corner was 125 cm, and the delta V was calculated to be approximately 71 kph. As shown in Figure 11, there was extensive interior intrusion into the driver's seating area. In the driver's compartment, the instrument panel was displaced 21 cm rearward, the toe pan was displaced 63 cm rearward, the kick panel was displaced 37 cm to the right, the steering wheel was displaced 9 cm to the rear (shown in Figure 12), and the floor was displaced 10 cm up.

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, she was taken to the operating room where 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. Gross weight of the stillborn was 3.75 kg.

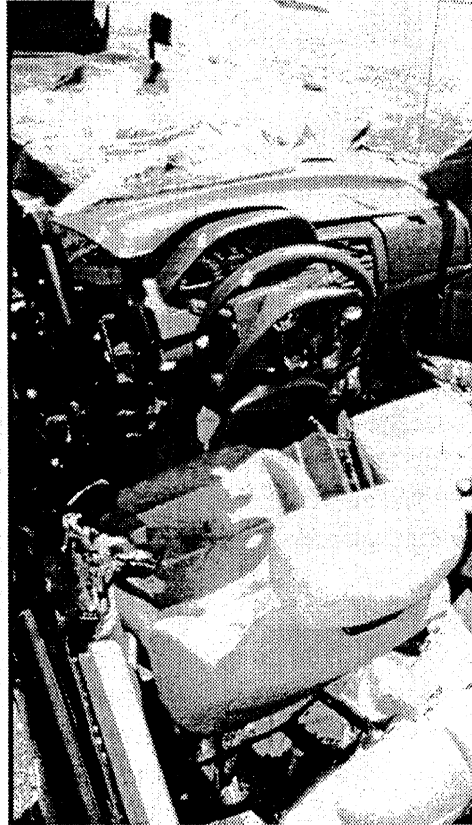


Figure 11. Intrusion into the driver's compartment in case GMP-010.

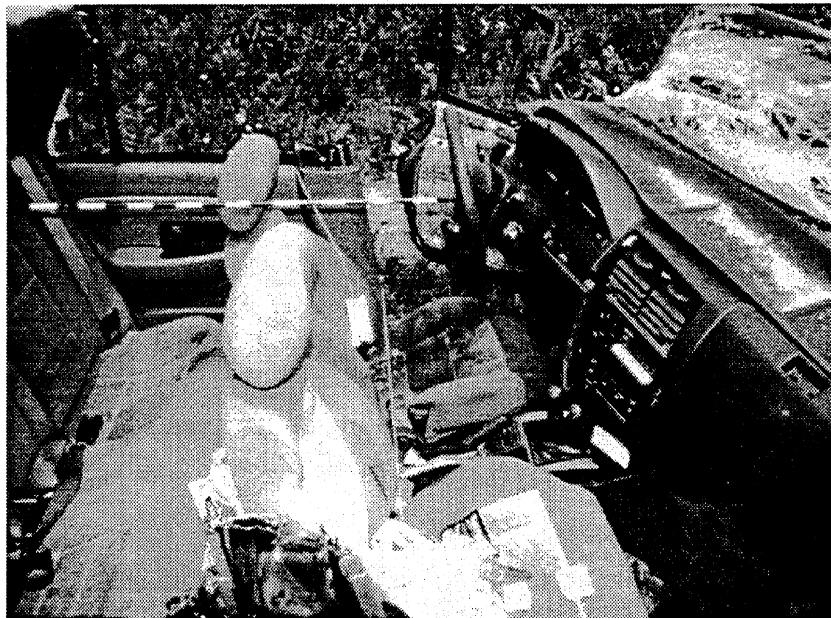


Figure 12. Steering wheel deformation in case GMP-010.

The belt-restrained pregnant driver sustained a left orbital wall fracture (AIS 2), multiple teeth fractures and avulsions, and numerous integumentary facial injuries (AIS 1) from facial contact with the steering wheel. She sustained contusions to the left side of her neck and left shoulder (AIS 1) from the automatic shoulder belt, and a contusion to her

right chest and abdomen (AIS 1) from the belt webbing or steering wheel. In addition, she sustained a comminuted fracture to her left femur (AIS 3), a nondisplaced left tibial plateau fracture (AIS 2), a fracture to the right fibular head, and ligament injuries to her right knee (AIS 2). She also sustained a right calcaneus fracture (AIS 2) and multiple right leg contusions (AIS 1). It is suspected that abdomen contact with the steering wheel or lap belt resulted in the placental abruption (AIS 4) and fetal loss.

GMP-013

Conditions were dark and unlit when the case vehicle, a 1988 Ford Aerostar, left the roadway and struck a large boulder with its front end. After the initial impact, the Aerostar rolled over one-quarter turn and came to rest on its left side to the left of the boulder. The direct damage extended 120 cm across the front and the maximum crush was 73 cm to the left front bumper corner. The equivalent barrier speed of the impact is estimated to have been approximately 68 kph. The unbelted driver was fatally injured.

The 32-year-old (163 cm, 76 kg), 28 week pregnant occupant was unrestrained in the left-rear seat. At the time of the crash, she was asleep, lying across the seat with her head placed on a large cooler. She experienced brief loss of consciousness (AIS 2) and was transported to the hospital. She sustained a pedicle fracture at C5 (AIS 3), fracture subluxation at C5/C6 with narrowing of the spinal canal (AIS 2), a left upper-arm laceration, contusions and lacerations to her right leg, and right shoulder strain (AIS 1).

Initial diagnosis of the fetus was good, but hydrocephaly resulting from intraventricular hemorrhage (AIS 4) was diagnosed by ultrasound within a few days of the crash. A 2.84 kg infant was vaginally delivered at 38 weeks gestational age approximately 10 weeks after the crash and suffered from hydrocephaly.

GMP-206

The pregnant driver was traveling at a driver-estimated speed of 72 kph when she struck the rear of a stopped vehicle. The damage was reported to be moderate to the front of the vehicle and the equivalent barrier speed is estimated to have been greater than 48 kph. The female driver was wearing the three-point belt and was 28 weeks pregnant. She sustained a contusion to her head (AIS 1) from an unknown source, and a contusion across her abdomen (AIS 1) from the lap portion of the belt webbing.

She was transported to the emergency department after the crash and sent home within a few hours. The next day, she returned to the hospital because of massive maternal bleeding, and the baby was delivered stillborn.

GMP-214

Rainy conditions were present when a 1995 Ford Escort Station Wagon was involved in an offset-frontal crash with a 1988 Acura Legend that had crossed the centerline of a four-lane road. The direct damage began at the left-front bumper corner on the Escort and extended 81 cm across the front, resulting in a 55% vehicle overlap. The maximum crush

was 81 cm to the left-front bumper corner, and the delta V was calculated to be approximately 53 kph. In the driver area, there was 25 cm of rearward intrusion of the toepan, 18 cm of the steering wheel, and 16 cm of the instrument panel.

The 37-year-old female driver was approximately 36 weeks pregnant. She was wearing the automatic shoulder belt but not the manual lap belt, and the airbag deployed. She sustained unknown injuries that were estimated to be moderate in severity.

The fetus died in utero with a possible placental abruption. There was deformation to the upper half of the steering wheel rim as shown in Figure 13.



Figure 13. Steering wheel deformation for case GMP-214.

4.3.3 Summary of Moderate Frontal Impacts

Eight cases involved frontal impacts with estimated crash severities between 24 and 48 kph. Three of these involved good fetal outcomes, one resulted in normal delivery within 24 hours, one had contractions that subsided without intervention, one baby was born shortly after the crash and suffered complications from premature birth and in utero head trauma, one baby was born 2 months after the crash with head injuries, and one fetus died as a result of placental abruption. All of the mothers wore three-point belts, and five were also restrained by the deploying airbag. In the two cases with the major neonatal complications and in one case with good fetal outcome, the mother sustained moderate injuries. In the other cases, the mothers sustained minor injuries or were uninjured.

These eight cases involved four drivers and four right-front passengers, with two of the most serious fetal outcomes occurring to drivers and one to a right-front passenger. Five of the pregnant occupants involved in moderate frontal impacts were at least 36 weeks pregnant and had good fetal outcomes or only minor complications. The three most serious fetal outcomes were to fetuses of 24, 25, and 30 weeks gestational age.

4.3.4 Case Narratives for Moderate Frontal Impacts

GMP-008

A 1985 Honda Civic sustained frontal damage when it struck the left side of a 1995 Dodge Neon that had entered an intersection at a stop sign. The direct damage began at the right-front bumper corner and extended 121 cm across the front, resulting in 77% vehicle overlap. The damage to the front of the Civic was moderate with a maximum crush of 25 cm to the center portion of the bumper. The equivalent barrier speed is estimated to have been approximately 25 kph.

The 26-year-old pregnant (157 cm, 72 kg) right-front passenger was wearing the three-point belt, had her seat in a midtrack position, and reportedly was wearing the lap portion of the three-point belt properly positioned below her pregnant abdomen. She was 36 weeks pregnant and did not sustain any injuries as a result of the crash.

She was transported to the hospital with complaints of lower anterior abdominal pain. A monitor indicated that she was experiencing contractions. Over the next 2 hours her contractions and pain subsided, and she was discharged home. Twenty days after the crash, she delivered a healthy 3.49 kg infant at 39 weeks gestational age. Apgar scores were 9 and 9 at 1 and 5 minutes, respectively.

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. The direct damage to the Maxima began at the left-front bumper corner and extended 110 cm across the front, resulting in 71% vehicle overlap. The damage to the front was moderate, with a

maximum crush of 32 cm to the center portion of the front bumper. The equivalent barrier speed was 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. 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 14. The front of her abdomen and her knees were approximately 44 and 28 cm from the instrument panel, respectively. She sustained an abrasion just under her chin (AIS 1) from the deploying airbag. She sustained a contusion across her right shoulder and chest (AIS 1), and a fracture to her sternum (AIS 2) from loading by the shoulder portion of the three-point belt. In addition, she sustained a contusion to her lower abdomen (AIS 1) from the lap portion of the belt, and an abrasion to her right thigh (AIS 1) from the deploying airbag or the lap portion of the belt.



Figure 14. Approximate occupant position and posture at the time of the crash for case GMP-023.

After the crash, she was transported to the hospital by ambulance. The fetus was monitored and maintained a good heart rate, so the mother was discharged home within 24 hours of the crash. Approximately 2 weeks after the crash, at a gestational age of 39 weeks, she vaginally delivered a healthy baby girl (3.46 kg). Apgar scores were 9 and 9 at 1 and 5 minutes, respectively. The infant sustained a fracture to the midshaft of her left clavicle (AIS 2) during delivery that was not related to the crash.

GMP-025

Weather conditions were good when the case vehicle, a 1998 Dodge Stratus, struck a stopped 1996 GMC K1500 pickup in the rear. Damage to the front of the Stratus was moderate, with a maximum crush of 40 cm to the center portion of the front bumper. The

direct damage extended 150 cm across the entire front of the vehicle and 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. She was wearing the three-point belt and the airbag deployed, and she reportedly had the seat in the midtrack position. During the frontal impact, the pregnant driver moved forward into the three-point belt and deploying airbag. As the airbag deployed, it flung her left hand into the left-upper corner of the windshield, resulting in a contusion to her left hand (AIS 1). She sustained a contusion to her right hand (AIS 1) possibly from the steering wheel, and her left knee contacted the knee bolster, resulting in a contusion (AIS 1).

After the crash, she was transported to the hospital. The fetus maintained a good 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 vaginally delivered a healthy 3.20 kg baby.

GMP-026

This crash occurred on a two-lane, rural roadway. A 1994 Mitsubishi Gallant struck the case vehicle, a 1998 Chevrolet Cavalier, in the front. Direct damage to the front of the case vehicle was distributed 109 cm across the full width. This frontal impact crushed the front structure to a maximum depth of 57 cm at the center portion of the front bumper. Using the WinSmash reconstruction program, and a PDOF of 345°, the delta V was estimated to be approximately 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 rear-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. During the frontal impact, the pregnant occupant moved forward into the three-point belt and the airbag. From shoulder- and lap-belt loading, she sustained an abrasion over the right clavicular region (AIS 1) that extended diagonally downward towards the left and a contusion under the left breast and across the flank (AIS 1). In addition, she sustained an abrasion and contusion to the abdomen (AIS 1) from the lap portion of the belt restraint. As a consequence of bracing with her right arm against the instrument panel, she sustained a comminuted fracture to the distal right radius (AIS 3). The deploying airbag struck the passenger on the dorsal aspect of the right hand, which was braced against the instrument panel. From this airbag contact, she sustained a small abrasion to the distal middle finger of the right hand and a contusion to the distal right thigh (AIS 1). She sustained comminuted fractures to the distal right and left tibia and fibula (AIS 2) from contact with the toepan. In addition, she sustained a laceration to her right leg and a contusion to her right knee (AIS 1) from contact with the knee bolster.

Approximately 9 weeks after the crash at a gestational age of 39 weeks, the mother vaginally delivered a 2.52 kg baby. The infant sustained a right clavicle fracture as a result of difficult childbirth. The infant was admitted to the hospital at 7 days old 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.

GMP-203

The case vehicle, a 1993 Ford Taurus, was southbound at an unknown speed when a 1991 Ford Ranger, traveling north, crossed the centerline and entered the southbound lane. The driver of the Taurus was unable to avoid being struck head-on by the Ranger. Damage to the front of the Taurus was severe with a maximum crush of 74 cm to the left-center bumper. Direct damage began at the left-front bumper corner and extended 81 cm across the front, resulting in 54% vehicle overlap. The equivalent barrier speed is estimated to have been approximately 43 kph based on crush measurements of the vehicle. The pregnant occupant was seated in the right front, and there was approximately 8 cm of rearward intrusion of the toe pan, and 6 cm of rearward intrusion of the glove compartment in this area.

The 25-year old (168 cm, 70 kg), right-front passenger was 40 weeks pregnant. She was wearing the three-point belt, and during the frontal impact, she moved forward into the belt restraint. She sustained an abrasion to her forehead (AIS 1), possibly from head contact with the roof liner, and she sustained cervical strain. The pregnant occupant sustained an abrasion across her chest and abdomen from loading by the shoulder portion of the belt, and contusions to both hands (AIS 1) from contact with the windshield or the instrument panel. In addition, she sustained abrasions to her right and left knees (AIS 1), and a sprain to her left knee (AIS 2) from contact with the glove compartment. The right-front passenger was transported to the hospital after the crash, where she delivered a healthy baby within 24 hours.

GMP-208

The case vehicle, a 1990 Toyota Celica, was struck in the left-front corner by a four-door Buick that turned into the path of the case vehicle at an intersection. Damage to the Toyota was reportedly moderate with an estimated equivalent barrier speed between 24 and 48 kph.

The female driver (173 cm, 68 kg) was reportedly wearing the three-point belt and was 24 weeks pregnant. She did not sustain any visible injuries and did not seek medical attention after the crash.

She reportedly began vaginal bleeding the morning after the crash, and a placental abruption was suspected during a previously scheduled visit to her doctor later that day. One week after the crash, she delivered a 0.68 kg infant who died 1 hour after birth because of prematurity.

GMP-211

A 1997 Dodge Grand Caravan was traveling in the left westbound lane on a wet, five-lane roadway. A 1989 Ford Mustang was traveling eastbound when its driver lost control of the vehicle, which rotated counterclockwise, crossed the center turn lane, and was struck in the right-front wheel by the front of the Caravan. After the impact, both vehicles rotated, causing a second impact between the left side of the Caravan and the right side of the Mustang. The Caravan continued to rotate and was struck in the left side by the front of a 1995 Dodge Neon. The back plane then endswiped a wall which bordered the north sidewalk adjacent to the roadway. The direct damage extended across the front and left side of the Caravan with a maximum crush of 61 cm. The delta V of the Caravan in the frontal impact was estimated to be approximately 31 kph.

The 26-year-old (155 cm, 82 kg) pregnant, short-statured driver was wearing the three-point belt and the airbag deployed. She was 39 weeks pregnant. She sustained a dislocation to her left acromioclavicular joint (AIS 2) from shoulder-belt loading, a mesenteric laceration (AIS 2) from the lap portion of the belt or steering wheel, a fracture to her right first metatarsal (AIS 2) from the foot controls, and multiple abrasions and contusions (AIS 1).

Initial diagnosis of the fetus was good. The baby was delivered the day after the crash by planned cesarean section. Birth weight was 4.25 kg and Apgar scores were 6 and 9 at 1 and 5 minutes, respectively. The baby was healthy and had no injuries from the crash.

GMP-216

On a windy, rainy day, the driver of this 1993 Toyota Tercel was traveling in the right lane at a witness-estimated speed between 56 and 65 kph. The pregnant driver was distracted by problems with discarding a cigarette, and the vehicle exited the right side of the road and struck a utility pole with its front end. The damage was severe to the front and the equivalent barrier speed was estimated to be between 24 and 48 kph.

The 29-year-old (157 cm, 52 kg) female driver was 25 weeks pregnant and claimed to be wearing the three-point belt, although the evidence of belt loading (marks on the belt) may have been from another crash. During the frontal impact, the airbag deployed, and the driver moved forward into the belt and airbag restraints. Medical records indicate that she sustained a laceration to her lower lip (AIS 1) from the deploying airbag, and a fracture to her left clavicle (AIS 2), probably from the shoulder portion of the three-point belt. In addition, she sustained a 2 cm laceration to her right knee and a 1 cm laceration to the medial aspect of her left knee (AIS 1) from the knee bolster. The pregnant driver sustained a fracture to her right talus and a right calcaneal fracture (AIS 2) from contact with the toe pan or foot controls. In addition, she sustained a partial placental abruption (AIS 3).

Three days after the crash, at a gestational age of 25 weeks, the pregnant driver delivered a 0.62 kg baby boy. Apgar scores were 7 and 7 at 1 and 5 minutes, respectively. The infant developed perinatal asphyxia secondary to placental abruption, and subsequently

experienced bradycardia with some episodes of apnea. A head ultrasound demonstrated grade IV intraventricular hemorrhage and intraventricular/intraparenchymal hematoma, with a clot in the left lateral ventricle, from prematurity and possibly trauma. He was also anemic (fetomaternal hemorrhage secondary to trauma). Chest x-ray findings were consistent with respiratory distress syndrome and bronchopulmonary dysplasia.

4.3.5 Summary of Minor Frontal Impacts

Fifteen cases involved minor frontal impacts with severities less than 24 kph. Two cases resulted in major complications for the fetus. One of these resulted in a placental abruption and uterine laceration resulting in premature emergency cesarean delivery. In the other case, the mother died shortly after the crash, but the infant was delivered by emergency cesarean section. Three other crashes led to uterine contractions. The remaining ten cases all had good fetal outcomes.

In the case with the maternal death, the mother was improperly restrained by only a shoulder belt and bled to death from heart and spleen injuries. In the other case with the major fetal complication, the mother was restrained by an airbag and three-point belt and received only minor injuries besides the placental abruption and uterine lacerations. In all other minor frontal impact cases, the maternal injuries were minor or none. Two of these mothers were unrestrained, four were wearing a three-point belt, six were wearing a three-point belt and the airbag deployed, and two were unbelted but the airbag deployed.

The pregnant occupant was the driver in ten cases (including the placental abruption/uterine laceration case), the right-front passenger in four cases (including the maternal death case), and the rear passenger in one case. Three occupants had reached a gestational age between 20 and 23 weeks, five had reached 24 to 27 weeks, two had reached 28 to 31 weeks, one was at 35 weeks, and four reached more than 36 weeks.

4.3.6 Case Narratives for Minor Frontal Impacts

GMP-003

The case vehicle was a 1986 Ford Tempo that struck the rear of a 1984 Mercedes-Benz that had stopped for traffic on a limited-access highway. The direct damage began at the left-front bumper corner and extended 64 cm across the front of the Tempo, resulting in 43% vehicle overlap. The maximum crush was 6 cm to the left-front bumper corner. Using the WinSMASH crash reconstruction program and c-values for the Tempo, the equivalent barrier speed was estimated to have been 12 kph.

An unbelted 18-year old female (157 cm 70 kg) who was 39 weeks pregnant was seated in the right front. During the frontal impact, she moved forward and to the left, and contacted the rearview mirror with her head, resulting in a contusion to the left side of her forehead (AIS 1). She sustained a contusion to the right side of her back (AIS 1), probably from contact with the side door interior.

Initial diagnosis of the fetus was good. The infant was delivered vaginally 16 days after the crash at 41 weeks gestational age. Birth weight was 3.46 kg with Apgar scores of 7 and 9 at 1 and 5 minutes, respectively. The child was discharged in healthy condition after treatment for a cleft palate unrelated to the crash.

GMP-005

The roads were wet when a 1989 Ford LTD Crown Victoria stopped quickly on a limited-access highway. The pregnant driver of a 1996 Toyota Corolla was traveling behind the LTD. Although she applied the brakes and steered to the left, she was unable to avoid striking the rear of the LTD. Damage to the front of the Corolla was moderate with a maximum crush of 21 cm above the right-front bumper corner. The direct damage began at the right-front bumper corner and extended 44 cm across the front, resulting in 34 % vehicle overlap. The delta V was calculated to be approximately 12 kph.

The 30-year-old (175 cm 102 kg) driver was not wearing the three-point belt, but the airbag deployed. She was 23 weeks pregnant. Measurements were taken of the seat position after the impact, and the mother was subsequently photographed and measured in the vehicle at her approximate seating position as shown in Figure 15. With these settings, the front of her abdomen was approximately 14 cm from the bottom of the steering-wheel rim. During the impact, her chest contacted the deploying airbag, resulting in a contusion to the center portion of her chest (AIS 1). Her head contacted the lower-left corner of the sunvisor, resulting in an abrasion to her mid forehead (AIS 1), and she sustained a contusion to the medial aspect of her left knee (AIS 1) from contact with the knee bolster.

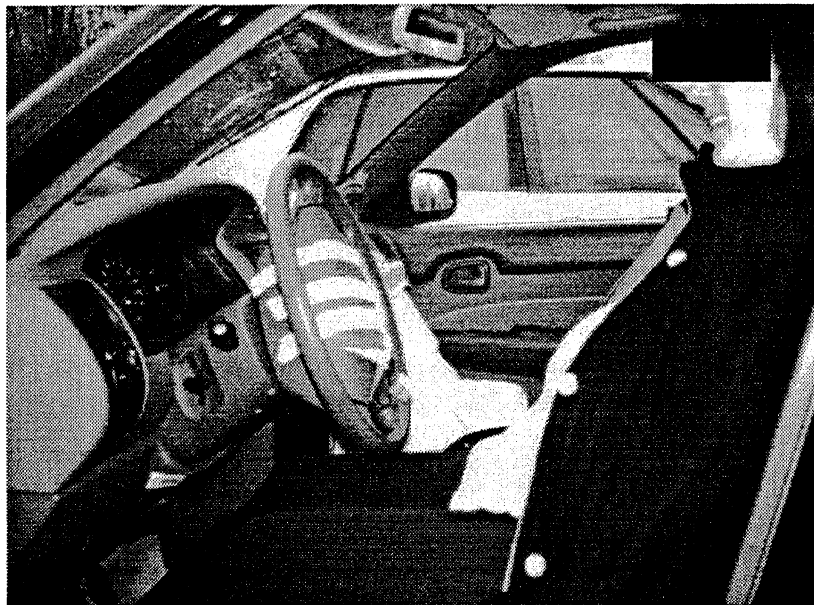


Figure 15. Approximate occupant position at the time of the crash in case GMP-005.

After the crash, the driver was transported to the hospital via ambulance. Measurement of fetal heart rate was normal, and the occupant was discharged within 12 hours of the

crash. Labor began at a gestational age of 41 weeks and a decision was made to deliver the baby by cesarean section because of failure to progress. A 4.11 kg healthy female was born with Apgar scores of 8 and 9 at 1 and 5 minutes, respectively. No neonatal injuries resulted from the motor-vehicle crash.

GMP-006

The case vehicle, a 1993 Dodge Caravan, was stopped on a two-lane roadway, and the driver was waiting to make a left turn into a private drive. The driver attempted to cross the lanes when a 1992 Chevrolet Cavalier, traveling in the opposite direction, struck it in the front. At the time of the vehicle inspection, the front bumper, grille and left-front fender were detached from the Caravan and unavailable for inspection. The estimated equivalent barrier speed is less than 24 kph.

The 27-year-old female (170 cm, 91 kg) driver was 35 weeks pregnant. She was wearing the three-point belt and the airbag deployed. She sustained a contusion to her right breast and abdomen (AIS 1) from the belt webbing, and a contusion to her forehead from the airbag (AIS 1). In addition, 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 abortion (33%) was also diagnosed (AIS 4).

On hospital admission, the mother was experiencing abdominal pain and contractions approximately 3 minutes apart. Measurement of fetal heart rate indicated fetal distress, and a decision was made to deliver the baby by cesarean section within 3 hours of the crash. Apgar scores were 9, 2, and 9 at 1, 5 and 10 minutes, respectively. 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.

GMP-009

A 1996 Toyota Camry was turning left when it struck the front of the case vehicle, a 1996 Chevrolet Lumina. Damage to the Lumina was moderate with a maximum crush of 14 cm to the center portion of the front bumper. The direct damage began at the left-front bumper corner and extended 120 cm across the front, resulting in 71% vehicle overlap. Crush measurements were obtained, and the equivalent barrier speed was estimated to have been approximately 16 kph.

The 23-year-old female (170 cm, 88 kg), right-front passenger was wearing the three-point belt and the airbag deployed. She sustained contusions and lacerations to her lips, an abrasion to her chin, and an abrasion to her right anterior wrist (AIS 1) from the deploying airbag. Both of her knees contacted the glove compartment, resulting in an abrasion to her left knee and a contusion to her right knee (AIS 1).

She was 31 weeks pregnant 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 vaginally delivered a healthy 3.57 kg baby girl. Apgar scores were 8 and 9 at 1 and 5 minutes, respectively.

GMP-014

A 1988 Dodge Dynasty was turning left into a private driveway and was struck by the case vehicle, a 1995 Chevrolet Lumina, that was traveling in the opposite direction. The direct damage began at the left-front bumper corner and extended 96 cm across the front, resulting in 63% vehicle overlap. The damage was minor with a maximum crush of 3 cm to the left-front bumper corner. Using crush measurements and the WinSMASH program, an equivalent barrier speed of 11 kph was estimated.

The 40-year-old (163 cm, 70 kg) driver was 26 weeks pregnant. She was wearing the three-point belt and the airbag deployed. She sustained a contusion across her left shoulder and left chest (AIS 1) from loading by the shoulder belt. The driver reportedly applied the brake with her right foot just before the impact occurred, resulting in a sprain to her right foot (AIS 1). She also sustained contusions to the top of her right foot (AIS 1), probably from contact with the brake pedal.

At the hospital, the initial diagnosis of the fetus was good, and the pregnant driver was discharged in good condition. She vaginally delivered a healthy baby boy 14 weeks after the crash at a gestational age of 40 weeks. The baby weighed 4.11 kg and Apgar scores were 9 and 9 at 1 and 5 minutes, respectively.

GMP-015

The case vehicle, a 1997 Mercury Sable, was traveling east at an unknown speed on a two-lane roadway. It was raining and the roads were wet. As the Sable approached a private drive, a 1996 GMC Sonoma pulled out from the intersecting driveway and crossed into the path of the Sable as it began a left turn. The left-front bumper of the Sable struck the left side of the Sonoma. Direct damage length to the Sable was 34 cm and began at the left-front bumper corner, resulting in 31% vehicle overlap. The maximum crush was minor with only 1 cm of crush to the left-front bumper corner. Both vehicles were inspected and measured, and the delta V for the Sable was estimated to be approximately 12 kph.

The 17-year-old female (180 cm, 68 kg) driver was wearing the three-point belt and the airbag deployed. She was 27 weeks pregnant. She sustained a distal right radius (AIS 2) and scaphoid fracture (AIS 2), probably as a result of direct loading by the deploying airbag and module cover. She also sustained a contusion to her left cheek (AIS 1) from contact with the deploying airbag.

After the crash, the driver was transported to the hospital by ambulance where the baby was monitored. The fetus was healthy and the mother was discharged in good condition. Approximately 2 months after the crash, at a gestational age of 35 weeks, she delivered a 2.18 kg baby boy. Apgar scores were 9 and 9 at 1 and 5 minutes, respectively. The

neonate had dyspnea and respiratory abnormalities resulting from premature birth that was unrelated to the crash, and was discharged in good health.

GMP-016

This was a head-on crash involving the case vehicle, a 1994 Suzuki Swift, and a 1990 Mercury Sable. The pregnant occupant was driving the Swift, attempted to turn left at an intersection, and was struck in the front by the Sable that was traveling in the opposite direction. The direct damage to the Swift extended 135 cm across the entire front, with a maximum crush of 19 cm to the right-front bumper corner. The equivalent barrier speed was 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. On impact, she moved forward into the belt restraint and her breasts may have contacted the steering wheel. She sustained a contusion to her left breast from the belt webbing or the steering wheel and a contusion to her right breast (AIS 1) from the steering wheel. She sustained a sprain to her right ankle (AIS 1), probably from the brake pedal, and a contusion to the lateral portion of her right upper arm (AIS 1) from an unknown interior source.

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 2.87 kg baby boy after a normal delivery. Apgar scores were 5 at 1 minute and 9 at 5 minutes.

GMP-018

The pregnant driver of a 1997 Dodge Neon was traveling at a driver-estimated speed of 89 kph on a two-lane roadway in a rural area when her vehicle struck a deer that was crossing the road. The damage to the front of the Neon was minor with a maximum crush of 13 cm above the front bumper. This vehicle is equipped with frontal-impact airbags, which did not deploy during the minor frontal impact. The equivalent barrier speed was estimated to be less than 24 kph.

The 35-year-old female (163 cm, 58 kg) driver was not wearing the available three-point belt and was 21 weeks pregnant. She sustained cervical strain (AIS 1) from impact forces.

She was transported to the hospital where fetal monitoring showed a good heart rate, and the mother was discharged home within 6 hours of the crash. A healthy 3.55 kg baby was vaginally delivered 19 weeks after the crash at a gestational age of 40 weeks.

GMP-019

At an intersection, a 1997 Buick LeSabre struck the case vehicle, a 1988 Pontiac Sunbird, in the front. Damage to the front of the Sunbird was very minor, with a maximum crush

of 4 cm to the right-front bumper corner. The direct damage began at the right-front bumper corner and extended 45 cm across the front, resulting in 36% vehicle overlap. The delta V for the Sunbird was estimated to have been about 12 kph.

The 24-year-old (163 cm, 78 kg) female driver was 26 weeks pregnant. She reportedly had the seat adjusted to the forward-most seat-track position. With this position, the center of the steering-wheel hub was about 55 cm from the center of the seatback. Measurements were taken of the seat position after the impact, and the mother was subsequently photographed and measured in the vehicle at her approximate seating position as shown in Figure 16. With these positions, the front of her abdomen was approximately 6 cm from the bottom of the steering-wheel rim. She was wearing the three-point belt and did not sustain any injuries.



Figure 16. Approximate occupant position at the time of the crash for case GMP-019.

She went to the hospital approximately 2 hours after the crash with pain in her left lower abdomen. At the hospital, the fetus maintained good heart rate and an ultrasound was normal. The mother was discharged within 6 hours of the crash. A healthy 3.46 kg baby was delivered by cesarean section 14 weeks after the crash at a gestational age of 40 weeks. Apgar scores were 8 and 9 at 1 and 5 minutes, respectively.

GMP-020

The pregnant driver of this 1997 Mercury Villager initially failed to see that the vehicles in front of her were stopped. She applied the brakes but was unable to avoid striking the rear of a 1987 Nissan Sentra at a slow rate of speed. Damage to the front of the Villager was minor with a maximum crush of 9 cm to the right-front bumper corner, and a delta V of approximately 11 kph. The direct damage began at the right-front bumper corner and extended 42 cm across the front, resulting in 35% vehicle overlap.

This short-statured (160 cm, 68 kg), 31-year-old female driver had the seat adjusted to the forward-most seat-track position. She was 24 weeks pregnant. During the frontal impact, she moved forward into the three-point belt restraint and sustained an abrasion to her left shoulder (AIS 1).

At the hospital, the baby was monitored, the fetus maintained good heart rate, and an ultrasound was normal. The mother was discharged within 6 hours of the crash. Approximately 16 weeks after the crash, the occupant delivered a healthy 3.21 kg infant at a gestational age of 40 weeks. Apgar scores were 7 and 9 at 1 and 5 minutes, respectively.

GMP-022

The case vehicle, a 1990 Ford Tempo, was traveling west at a police-estimated speed of 56 kph and approaching a four-leg intersection. A 1990 Chevrolet was eastbound and attempted to make a left turn in front of the Tempo at the intersection. Damage to the front of the Tempo was moderate, with a maximum crush of 39 cm to the center portion of the front bumper. The direct damage began at the left-front bumper corner and extended 96 cm across the front, resulting in 59% front-end overlap. Both vehicles were measured and the delta V is estimated to have been approximately 23 kph.

The 18-year-old female (160 cm, 52 kg), right-front passenger was wearing the automatic shoulder belt, but not the manual lap belt. She was 28 weeks pregnant. The seat may have been in the full-forward position, and she had her left foot up on the instrument panel above the glove compartment, as indicated by scuff marks shown in Figure 17. During the frontal impact, she moved forward and to the left relative to the vehicle interior. An unrestrained passenger in the 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 to the hospital. She sustained a small contusion to the left side of her chest (AIS 1), and oblique linear abrasion to the left side of her chest (AIS 1), and a spleen laceration (AIS 2) from automatic shoulder belt loading. In addition, she sustained a 1 cm laceration to the left atrial appendage of her heart (AIS 5) and contusions to the hilar regions of both lungs (AIS 4) from shoulder belt loading. She sustained contusions and abrasions to her right knee from contact with the glove compartment.

An obstetrician was in the emergency department when the patient arrived and quickly delivered the premature infant by cesarean section because of maternal death. There was no placental abruption. The 28 weeks gestational age infant suffered typical complications resulting from a premature birth, but showed no other problems of trauma.



Figure 17. Scuff marks showing evidence of pregnant occupant foot position on instrument panel in case GMP-022.

GMP-027

The case vehicle, a 1995 Dodge Neon, struck the rear of a 1991 Ford Escort that had stopped to make a left turn. Damage to the front of the Neon was moderate with a maximum crush of 7 cm to the right-front bumper corner. Direct contact damage began at the right-front bumper corner and extended 115 cm across the front, resulting in 75% vehicle overlap. Vehicle damage was measured and the equivalent barrier speed is estimated to have been 13 kph.

In addition to the airbag, the 33-year-old (160 cm, 86 kg), 38 weeks pregnant driver was wearing the three-point belt. She sustained a contusion to her abdomen (AIS 1) and an abrasion to her left hand (AIS 1) from the airbag. She sustained lacerations to her right hand (AIS 1) from broken glass.

Approximately 3 weeks after the crash, the patient delivered a healthy 4.17 kg baby by a planned cesarean section. Apgar scores were 9 and 9 at 1 and 5 minutes, respectively.

GMP-202

The roads were wet when the case vehicle, a 1996 Ford Contour, was traveling west at a driver-estimated speed of 48 kph. A 1995 Chevrolet Cavalier was traveling eastbound at an unknown speed and attempted to make a left turn in front of the Contour. The Cavalier struck the front-left corner of the Contour. The maximum crush to the Contour was 12 cm to the left-front bumper corner. The direct damage began at the left-front bumper corner and extended 44 cm across the front, resulting in 34% vehicle overlap. Both vehicles were measured and a 12 kph delta V was calculated.

The 25-year-old female (175 cm, 79 kg) driver was 38 weeks pregnant and was not wearing the three-point belt, but the frontal-impact airbag deployed. She sustained an abrasion to her right cheek (AIS 1), an abrasion to the right side of her neck, and a contusion to her central chest area (AIS 1), all from the deploying airbag. In addition, she sustained a contusion to the anterior area of her left forearm (AIS 1) from the airbag module cover, a contusion to her left knee from the knee bolster, and a contusion to her right knee (AIS 1) from the steering column.

The pregnant driver started having contractions immediately after the crash, which were stopped through medical intervention. After a short observation, the driver was discharged. Approximately 2 weeks after the crash, at a gestational age of 40 weeks, the patient delivered a healthy 4.09 kg baby girl.

GMP-204

The case vehicle, a 1994 Mercury Cougar, was southbound at an unknown speed when the driver fell asleep, exited the west edge of the roadway, and came back onto the road in the northbound lane. The front of the Cougar struck a 1983 Mercury Grand Marquis in the right side in the northbound lane. Direct damage to the Cougar began at the right-front bumper corner and extended 103 cm across the front, resulting in 62% vehicle overlap. The maximum crush was 39 cm to the right-front bumper corner, and the equivalent barrier speed was calculated to be approximately 19 kph.

The 22-year-old (165 cm, 86 kg) female, right-front passenger was wearing the three-point belt and the airbag deployed. She was 36 weeks pregnant and sustained contusions to her upper and lower lips, abrasions to her right cheek, and a laceration to her nose (AIS 1) from the deploying airbag. In addition, her right knee contacted the mid portion of the instrument panel above the glove compartment. This contact resulted in a contusion to her right knee, an abrasion to her right knee (AIS 1), and a laceration just below the right knee (AIS 1).

She experienced premature contractions 3-7 minutes apart during hospital treatment. She was given tocolytic agents to alleviate contractions, and was sent home with a strong fetal heart rate. She delivered a healthy baby 1 month later near the expected delivery date.

GMP-215

The pregnant rear-seat passenger was traveling in a 1997 Dodge Intrepid taxicab in slow, heavy traffic on an interstate when the Intrepid was struck in the rear by a 1997 Mazda 626. This impact pushed the Intrepid forward, where its front end struck a 1986 Volkswagen Quantum in the rear. The damage was minor to the front and rear of the Intrepid, with an estimated equivalent barrier speed of less than 24 kph.

The 33-year-old (173 cm, 61 kg), 27 weeks pregnant female passenger was seated in the right rear and was wearing the three-point restraint. She was transported to the hospital with complaints of abdominal cramping, but otherwise did not sustain any injuries. Fetal monitoring indicated that the fetus was in good condition and the pregnant passenger was

discharged within 5 hours of the crash. Approximately 12 weeks after the crash, at a gestational age of 39 weeks, a healthy baby girl (3.54 kg) was delivered vaginally.

4.3.7 Summary of Severe and Moderate Side Impacts

Two of the side impact crashes were rated severe, with crash severities greater than 48 kph, while three were considered moderate with severities between 24 and 48 kph. Fetal losses occurred in three cases as a result of maternal death. One of the pregnant mothers wore a three-point belt as a right-front passenger, but she and her fetus died in this near-side crash that was very severe. Another of the fetal losses occurred to an unbelted right-front pregnant passenger involved in a near-side crash, who died from complications from a femur fracture coupled with a severely lacerated liver. In this case, the fetus also sustained a broken humerus. The third case of maternal and fetal loss was to an unbelted driver in a far-side impact, who was projected across the vehicle and sustained fatal head injuries from contact with the right-side A-pillar. All of these fetuses were between 23 and 28 weeks gestational age.

In the two other severe/moderate side impacts, the fetus survived. One was a near-side impact to a driver wearing a three-point belt who sustained multiple pelvic fractures. It is suspected that the good fetal outcome resulted because the fetus was only 19 weeks gestational age at the time of the crash, and was small enough to be cushioned by the amniotic fluid and be unaffected by the compromised pelvic cavity. The other case with a good fetal outcome was a far-side crash to an unbelted right-front passenger of 22 weeks gestational age restrained by a frontal airbag.

4.3.8 Case Narratives for Severe and Moderate Side Impacts

GMP-002

The driver of a 1989 Ford Tempo lost control of the vehicle because of icy road conditions. The vehicle rotated counterclockwise and crossed the centerline where a 1993 Ford Ranger traveling in the opposite direction struck it in the right-side door. The maximum crush to the right-front door of the Tempo was 68 cm, and the delta V was approximately 42 kph. The following intrusions (shown in Figure 18) were measured: right-front door – 44 cm to left, right B-pillar – 37 cm to left, right roof side rail – 19 cm to left, and right A-pillar – 4 cm to left.

An 18-year-old female (160 cm 54 kg), right-front passenger was 28 weeks pregnant and was not wearing the automatic shoulder belt or the manual lap belt. On impact, she struck the door panel that had intruded approximately 44 cm. She sustained multiple injuries, including a liver laceration (AIS 4), and a fracture to her distal right femur (AIS 3) from contact with the right-side door interior. She sustained multiple integumentary injuries to her head, face, arms, legs and buttocks (AIS 1). The primary cause of maternal death was respiratory compromise resulting from multiple embolic phenomena (fluids from the femur fracture passing into the bloodstream and preventing normal lung function) complicated by severe hepatic trauma.

The 28 week fetus died as a result of the trauma sustained by the mother. The fetus sustained a fractured left humerus (AIS 2) probably due to contact by the side-door interior.

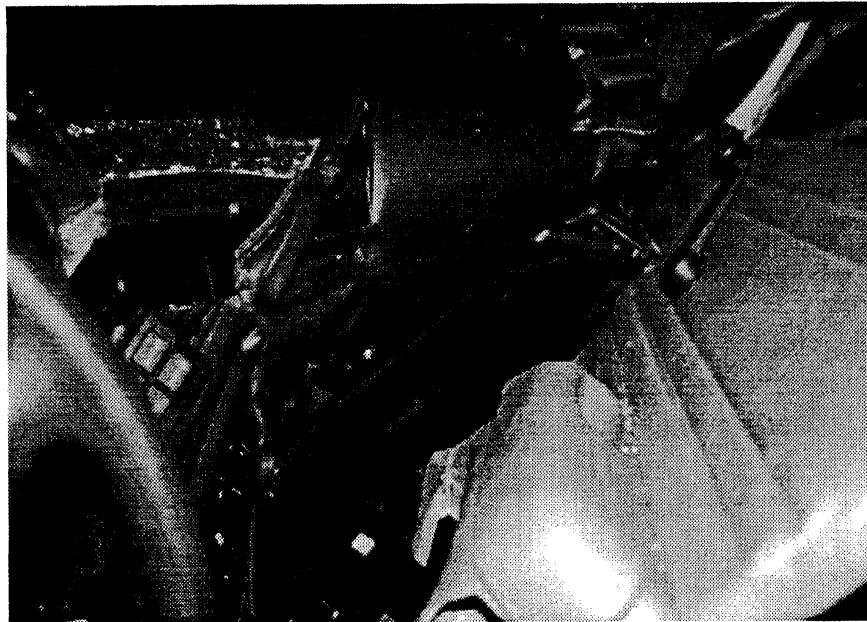


Figure 18. Intrusions into the front passenger compartment for case GMP-002.

GMP-004

The driver of a 1994 Ford Taurus pulled from a private drive into the path of a 1996 Ford Crown Victoria police vehicle, which struck the Taurus in the left-side door. Damage to the left side of the Taurus was severe, with a maximum crush of 50 cm to the driver's door panel. Using the WinSmash program, an equivalent barrier speed of approximately 37 kph was estimated for the Taurus. Interior intrusions (all to the right) included 41 cm to the door panel, 27 cm to the B-pillar, 26 cm to the A-pillar, 15 cm to the driver's seat cushion, and 11 cm to the roof side rail.

The 28-year-old female driver (173 cm 59 kg) was 19 weeks pregnant and was wearing the three-point belt. During the left-side impact, her left hip contacted the driver door, resulting in a left hip contusion (AIS 1) and multiple hip fractures, including bilateral superior pubic rami fractures, bilateral inferior pubic rami fractures, and a compression fracture to her sacrum (AIS 2). In addition, she sustained a separation to her pubic symphysis (AIS 3), a contusion to her right hip, and a contusion to her left knee (AIS 1).

She was initially transported to a nearby hospital and subsequently transferred to a level-1 trauma hospital approximately 6 hours after the crash. The fetus maintained a good heart rate and an ultrasound was normal. The mother was discharged within 2 days of the crash and her pelvic fractures were treated conservatively due to the pregnancy. The infant was delivered vaginally about 4.5 months after the crash at 38.5 weeks gestational age. Birth

weight was 2.72 kg and Apgar scores were 9 at 1 minute and 9 at 5 minutes. The baby was healthy with no problems, and the mother's pelvic injuries healed.

GMP-024

A 1997 Pontiac Sunfire crossed the centerline of a two-lane road and struck the left side of a 1995 Freightliner tractor-trailer that was traveling in the opposite direction. The direct damage extended down the left side from the left-front corner. The damage was extensive and the equivalent barrier speed was estimated to be less than 48 kph.

The 24-year-old (168 cm, 64 kg) right-front passenger was 22 weeks pregnant. She was not wearing the available three-point belt and the airbag deployed. She sustained contusions to both knees (AIS 1) from the glove compartment and the knee bolster.

She was transported to the hospital and the baby was monitored. She was discharged within 24 hours of the crash. Approximately 18 weeks after the crash at a gestational age of 40 weeks, the patient vaginally delivered a healthy 3.49 kg baby boy.

GMP-205

A 26-year-old pregnant driver of a 1989 Pontiac Grand Prix was traveling east at a high speed. The driver lost control of the Pontiac, which crossed the centerline and was struck in the right side by a 1988 Buick LeSabre that was traveling westbound. The police reported the damage to the right side of the Grand Prix to be severe with extensive right-interior intrusion. The equivalent barrier speed was estimated to be greater than 48 kph.

The 26-year-old female driver (173 cm, 68 kg) was not wearing the available three-point belt and was 23 weeks pregnant with twins. She died as a result of severe head injuries resulting from contact with the right A-pillar. The autopsy showed pinpoint hemorrhages in the pons over the roof of the fourth ventricle (AIS 5), subgaleal hemorrhage on the left side of the head (AIS 4), a hinge fracture across the middle cranial fossae (AIS 4), a diastatic fracture at the lambdoidal suture (AIS 2), and an abrasion to the right side of her forehead (AIS 1). She also sustained a fracture to her left pubic ramus (AIS 2), and multiple integumentary injuries (AIS 1).

Maternal death resulted in the death of both fetuses. There were no traumatic injuries to either fetus from the crash.

GMP-212

The driver of a Ford Escort Pony (the case vehicle) made a left turn in front of a 1991 GMC Sonoma pickup truck and was struck in the right side by the pickup truck. It is estimated that the Sonoma was traveling between 72-80 kph when it struck the Escort. The equivalent barrier speed for the right-side impact to the Escort is estimated to have been greater than 48 kph. Intrusion into the pregnant occupant's seating area is estimated to have been extensive.

The 36-year-old female right-front passenger was wearing the three-point belt and was 24 weeks pregnant. There was severe intrusion into the pregnant occupant's seating area, and she sustained fatal injuries. These included a transection of the cervical spinal cord (AIS 5), an odontoid fracture of the cervical spine (AIS 3), and abrasions to the right side of her neck, her jaw, and her right chest (AIS 1), probably from contact with the side door interior or the shoulder portion of the belt. In addition, she sustained an abrasion across her abdomen (AIS 1) from the lap portion of the three-point belt.

The fetus is assumed to have died as a result of maternal death.

4.3.9 Summary of Minor Side Impacts

Five cases were classified as minor side impacts with crash severities less than 24 kph. All were near-side impacts with respect to the pregnant occupant's location. Four cases where the mother was properly restrained by a three-point belt (one also with a frontal impact airbag) resulted in good fetal outcomes. Three of these women were drivers, while the fourth was a right-front passenger. The fifth case, involving an unrestrained right-front passenger, resulted in delivery within 18 hours of the crash and a fetal head injury sustained in utero. Maternal injuries in all five cases were minor or none. Gestational ages in these cases were 22, 31, 35, and 40 weeks for the good outcomes and 37 weeks for the case with the fetal head injury.

4.3.10 Case Narratives for Minor Side Impacts

GMP-001

A 1986 Chevrolet Cavalier, the case vehicle, was traveling southbound in the inside lane of a five-lane roadway when a 1993 Plymouth Sundance pulled from a private drive from the west and began merging across the southbound lanes. The driver of the Cavalier steered to the left, but was unable to avoid being struck in the right-front fender by the left rear of the Sundance. Direct damage to the Cavalier extended 65 cm along the right side, with a maximum crush of 10 cm to the right-front fender. The estimated equivalent barrier speed of the side impact was 9 kph.

A 21-year-old female (155 cm 85 kg) was the right-front passenger and was 37 weeks pregnant. She was not wearing the available three-point belt and her seat was positioned in the full-forward position. She sustained contusions and abrasions to the right side of her forehead (AIS 1) from contact with the A-pillar, and a contusion to her left knee (AIS 1) from contact with the area below the instrument panel.

The mother reported cessation of fetal movement after the impact. Her membranes broke 1.5 hours afterwards, and the infant was born vaginally within 18 hours of the crash. Birth weight was 3.18 kg. Apgar scores were 8 and 10 at 1 and 2 minutes, respectively. 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, rated 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.

GMP-007

A 1991 school bus was traveling south in the center-turn lane at slow speed. The case vehicle, a 1996 Jeep Grand Cherokee, was stopped facing east, waiting for southbound traffic to clear, to make a left turn. Southbound traffic stopped to let the Cherokee make its turn, and the driver began crossing the southbound lanes. As the Cherokee entered the turn lane, it was struck in the left front by the school bus. Damage to the left side of the Grand Cherokee was moderate with a maximum crush of 13 cm to the left-front fender. The direct damage began at the left-front corner and extended 300 cm rearward along the left-front fender and both left doors. The equivalent barrier speed is estimated to have been approximately 16 kph. The driver-side door panel intruded approximately 7 cm to the right.

The 32-year-old driver (157 cm, 59 kg) was 35 weeks pregnant. She was wearing the three-point belt, and on impact, moved to the left relative to the vehicle interior. She sustained a contusion to her upper-left hip (AIS 1) from contact with the side door and armrest, and a contusion to the lateral side of her left breast (AIS 1) from contact with the side door. In addition, she sustained a laceration to the left side of her head above her ear (AIS 1) from the flying side-rear window glass.

After the crash, she was transported to the hospital by ambulance where the baby was monitored. Initial diagnosis of the fetus was good, and the pregnant driver was discharged. A 3.35 kg infant was born 5 weeks after the crash at a gestational age of 40 weeks. Apgar scores were 9 and 9 at 1 and 5 minutes, respectively.

GMP-011

It was raining when a 1995 International tractor-trailer pulled out in front of a 1992 Plymouth Grand Voyager. The pregnant driver of the Voyager braked and steered to the right, but was unable to avoid being struck in the left side by the tractor-trailer. The equivalent barrier speed for the Voyager for this side impact is estimated to have been about 16 kph, but this estimate may be low because of underride damage. The maximum crush was 23 cm to the left-front fender, and the direct damage extended 222 cm rearward along the left-front fender and driver's door panel. The following are the maximum intrusions measured in the driver's area: A-pillar – 41 cm rearward and 10 cm to the right, window frame – 38 cm down, windshield – 50 cm rearward, instrument panel – 20 cm rearward, kickpanel – 12 cm to the right, and the windshield header – 11 cm down.

The 33-year-old female (157 cm, 69 kg) driver was 22 weeks pregnant. She was wearing the three-point belt and the airbag deployed, and reportedly had the seat in a midtrack position. During the impact, the left side of her head contacted the window frame and A-pillar, resulting in a loss of consciousness (AIS 2) at the scene, a concussion (AIS 2), an 8-cm laceration to the left temporal scalp, and two lacerations to the left side of her forehead (AIS 1). She sustained contusions to her knees (AIS 1) from contact with the

knee bolster, and a contusion to her right-lower aspect of her abdomen (AIS 1) from the lap portion of the three-point belt. She also sustained a contusion between her breasts from the shoulder portion of the three-point belt, and she sustained minor arm lacerations and contusions (AIS 1) from the side-door interior and window glass.

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 vaginally delivered a healthy 3.60 kg infant. Apgar scores were 9 and 9 at 1 and 5 minutes, respectively.

GMP-012

The driver of a 1997 Plymouth Voyager made a left turn in front of a vehicle in a private parking lot. The front of a 1997 4-door Ford sedan struck the Voyager in the right-front fender. The damage to the Voyager (the case vehicle) was minor with a maximum crush of 9 cm to the right-front fender. The direct damage extended 180 cm along the right-front fender and right-front door panel. The equivalent barrier speed was estimated to have been approximately 13 kph using the WinSmash program.

The 29-year-old (168 cm, 99 kg), right-front passenger was 31 weeks pregnant and was wearing the three-point belt. The vehicle was equipped with airbags, which did not deploy during this right-side impact. She did not sustain any injuries.

The pregnant passenger was transported to the hospital by ambulance where the baby was monitored and found to be in good condition. The mother was discharged within 12 hours of the crash. Eight weeks after the crash, at a gestational age of 40 weeks, the patient vaginally delivered a healthy 3.86 kg baby boy. Apgar scores were 9 at 1 minute and 9 at 5 minutes.

GMP-209

The driver of a 1986 Saab 900 pulled from a parking space into the path of a 1996 Chevrolet S-10 extended cab pickup. The pickup struck the Saab in the left-side doors. The maximum crush is estimated to have been approximately 9 cm to the left-rear door of the Saab, and the equivalent barrier speed is estimated to have been less than 24 kph.

The 28-year-old female (157 cm, 100 kg) driver was wearing the three-point belt and was 40 weeks pregnant. She did not sustain any injuries.

Initial diagnosis of the fetus was good. The pregnant driver vaginally delivered a healthy 4.00 kg baby 3 days after the crash at 40 weeks gestation. Apgar scores were 6 and 9 at 1 and 5 minutes, respectively.

4.3.11 Summary of Severe and Moderate Rear Impacts

Only one crash involved a rear impact with a severity greater than 24 kph, but it involved two pregnant occupants. Both were unbelted and suffered placental abruptions that required emergency cesarean delivery of premature infants. The right-front occupant delivered a neonate of 34 weeks gestational age, while the right-rear passenger delivered a baby of 32 weeks gestational age that may have suffered a head injury.

4.3.12 Case Narratives for Severe and Moderate Rear Impacts

GMP-207A and B

Road conditions were normal when a 1985 Buick LeSabre was traveling on a limited-access highway. Due to heavy traffic, the driver of the LeSabre was slowing down when it was struck in the rear by a 1987 Mack tractor-trailer. The LeSabre was reportedly pushed approximately 1000 feet down the road until it impacted the rear of a 1992 Honda Civic. Damage to the rear of the LeSabre was severe with a maximum crush of 146 cm to the left-rear bumper corner. The direct damage extended 168 cm across the entire rear of the vehicle. The damage to the front of the LeSabre was minor, with a maximum crush of 8 cm that extended 108 cm across the front. The equivalent barrier speed for the rear impact is estimated to have been approximately 77 kph. There was interior intrusion into the rear seating area.

(Occupant A) The 22-year-old, right-front female passenger (157 cm, 86 kg) was not wearing the three-point belt and was 34 weeks pregnant. During the rear impact, she moved rearward relative to the vehicle interior and into the seatback and head restraint. The unbelted rear occupants subsequently loaded the back of the right-front seat. The right-front passenger sustained a contusion to her forehead (AIS 1), probably from contact with the mid portion of the instrument panel, abrasions to the left side of her face (AIS 1), from flying glass, and a contusion to her right knee (AIS 1) from the lower portion of the instrument panel. She also sustained a placental abruption (AIS 3), probably from the seatback (shown in Figure 19) or frontal impact with the instrument panel on forward rebound. The placental abruption required an emergency cesarean section delivery the same day of the crash. The premature baby reportedly did not sustain any injuries from the crash and was healthy upon delivery.

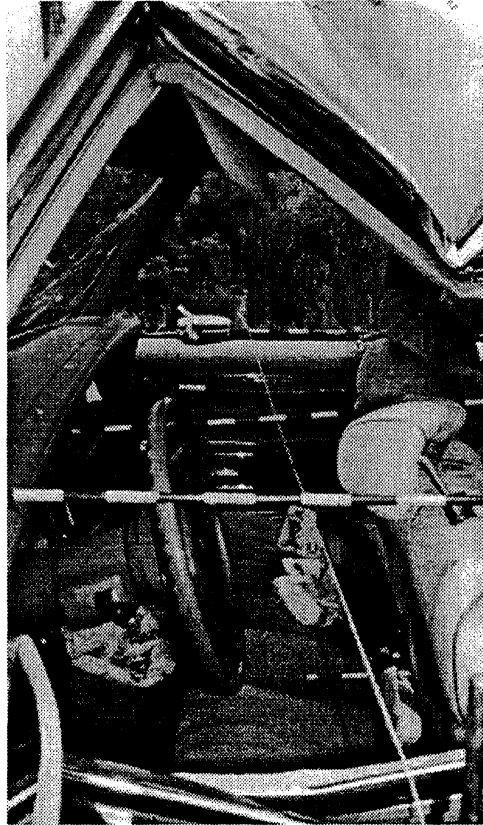


Figure 19. Damage to the right-front passenger compartment for case GMP-207A.

(Occupant B) The 20-year-old (150 cm, 94 kg), right-rear passenger was not wearing the available lap belt and was 32 weeks pregnant. On impact, she moved rearward relative to the vehicle interior into the intruding seatback (shown in Figure 20), resulting in a contusion to her lower back (AIS 1). She also sustained contusions to her right and left knees and her left chest (AIS 1), probably from contact with the front-seat seatback during the second impact or on forward rebound. She sustained a placental abruption (AIS 3), probably as a result of contact with the seatback or the front seatback on forward rebound. An emergency cesarean section delivery was necessary the same day of the crash. The premature baby reportedly has some health problems, with a possibility of a head injury.

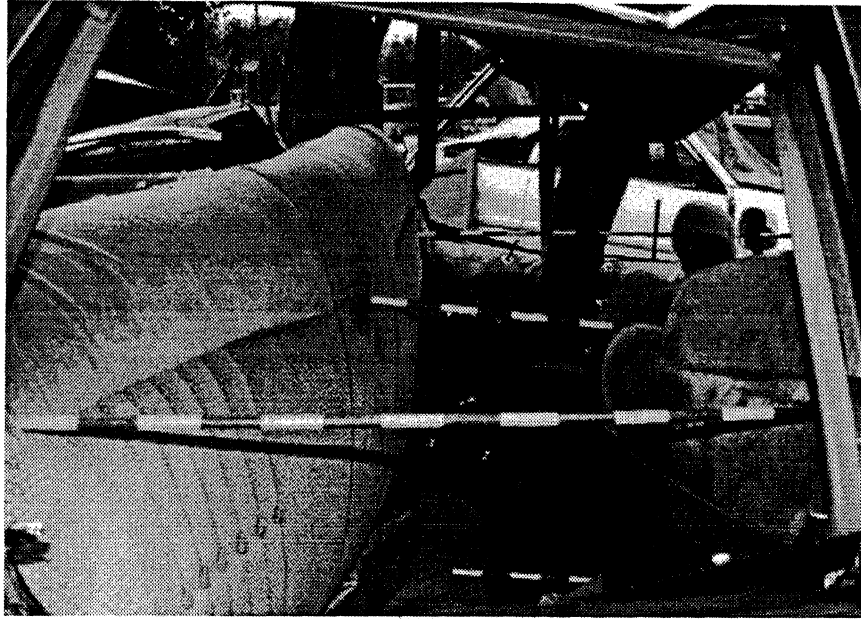


Figure 20. Rear compartment damage in case GMP-207B.

4.3.13 Summary of Minor Rear Impacts

Four cases involved minor rear impacts with estimated crash severities less than 24 kph. All involved pregnant drivers wearing three-point belt restraints. In all cases, the mother sustained only minor or no injuries. Two of the occupants had good outcomes with no injury or minor complications to the fetus. One driver experienced contractions after the crash that subsided without intervention. In the fourth case, the fetus died in utero shortly after the crash for unknown reasons without any signs of placental abruption or direct fetal injury. In this case, the mother was 26 weeks pregnant. In the other three cases, the pregnancies were at 24, 34, and 37 weeks' gestation.

4.3.14 Case Narratives for Minor Rear Impacts

GMP-017

A 1998 GMC Jimmy was stopped at a three-leg intersection waiting to make a left turn when a 1992 Chevrolet Cavalier failed to notice that the Jimmy was stopped and struck it in the rear. The direct damage to the Jimmy (the case vehicle) began at the left-rear bumper corner and extended 105 cm across the rear bumper. The maximum crush was 8 cm to the center portion of the rear bumper. The equivalent barrier speed is estimated to have been approximately 15 kph.

The 30-year-old (163 cm, 68 kg) driver was 24 weeks pregnant. She was wearing the three-point belt and sustained a contusion to the left posterior area of her head (AIS 1) from contact with the D-ring assembly or the B-pillar.

After the crash, she was transported to the hospital where initial diagnosis of the fetus was good. Approximately 16 weeks after the crash, at a gestational age of 40 weeks, the

driver vaginally delivered a healthy 3.66 kg infant. Apgar scores were 7 and 9 at 1 and 5 minutes, respectively.

GMP-021

An Oldsmobile Cutlass traveling at low speed struck a 1990 Honda Civic in the rear. There was only about 1 cm of crush to the rear bumper of the Civic 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 and was 26 weeks pregnant. She did not sustain any injuries.

The pregnant occupant 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 not alive. The patient did not have any other complications with the pregnancy. The autopsy of the 0.94 kg fetus did not indicate any anomaly other than the expected changes of a fetus that died in utero. Nothing was found that could be associated with trauma.

GMP-210

The case vehicle, a 1995 Saturn, stopped abruptly at a four-leg intersection to allow an emergency vehicle to cross the intersection. A full-size pickup truck travelling behind the Saturn was unable to stop and struck the Saturn in the rear. Damage to the rear of the Saturn was minor and extended across the rear of the vehicle. The equivalent barrier speed is estimated to have been less than 24 kph.

The 31-year-old (168 cm, 75 kg) driver was wearing the three-point belt and was 37 weeks pregnant. She reportedly had the seat in the full-rearward seat-track position. She sustained cervical strain (AIS 1) from impact forces.

The driver was transported to the hospital after the crash with mild contractions. The fetus was monitored for a few hours after the crash, and the driver was discharged within a few hours. Nineteen days after the crash, the pregnant driver delivered a healthy 3.43 kg infant at 40 weeks gestational age. Apgar scores were 9 and 9 at 1 and 5 minutes, respectively.

GMP-213

On a clear day, the case vehicle, a 1993 Jeep Grand Cherokee, was stopped for a stop sign at an intersection. The driver of a 1983 Chevrolet Citation failed to stop and struck the Cherokee in the rear. There was no visible damage to the rear of the Grand Cherokee and the estimated equivalent barrier speed is less than 24 kph.

The 30-year-old (165 cm, 96 kg) driver of the Cherokee was wearing the three-point restraint and did not sustain any injuries. She was 35 weeks pregnant at the time of the crash.

Initial diagnosis of the fetus was good, although the mother experienced abdominal cramping after the crash. A 3.83 kg baby was delivered 8 weeks after the crash at a gestational age of 42 weeks. Apgar scores were 3 and 8 at 1 and 5 minutes, respectively, because the cord was wrapped around the infants' neck at birth. The infant was given oxygen and discharged in healthy condition.

5.0 ANALYSIS

5.1 Factors Affecting Fetal Outcome

5.1.1 Approach

Although the number of cases in the UMTRI pregnancy crash database is not large, examining the statistical relationships between fetal outcome and various crash and occupant factors was expected to be informative. To do this, fetal outcomes were grouped into the following categories:

- 1 no fetal problems**
- 2 minor fetal problems**
early contractions or unscheduled delivery within 48 hours of the crash at a gestational age of at least 32 weeks
- 3 major fetal problems with fetal survival**
placental abruption, uterine laceration, direct fetal injury, or premature delivery within 48 hours of the crash before 32 weeks gestational age
- 4 fetal loss**

For each analysis, a two-way table was constructed with the crash factor forming the rows (e.g., categories of restraint use) and fetal outcome categories forming the columns. Each cell in the tables contains the observed number of case occupants that meet the variable requirements of the cell. Using these data, a chi-square test was conducted to determine if fetal outcome and the crash factor were independent.

For the crash factors shown to have a statistically significant relationship to fetal outcome, computation and inspection of the standardized residuals was performed to determine the pattern of the relationship. Standardized residuals are the differences between observed and expected number of cases in each cell divided by an estimate of the standard error. The expected number of cases in a cell is determined by multiplying row totals by column totals, and dividing by the sum of all rows and columns. Negative residuals indicate fewer observations than expected, and positive numbers indicate more observations than expected. Larger absolute values of the standardized residuals indicate a stronger association with fetal outcome.

5.1.2 Crash Severity and Restraint Usage

Table 3 shows the number of observed and expected cases, plus the calculated standardized residuals, for fetal outcome by impact severity. As might be expected, crash severity has a strong effect on fetal outcome in this study ($p=0.003$). The table also shows that minor crashes are most likely to have good fetal outcomes, and severe crashes are most likely to have negative fetal outcomes, because the standardized residuals become greater in absolute magnitude the farther they are towards the corners. In other words, observations of poor outcomes (major problems or fetal loss) are more strongly associated with more severe impacts, and observations of good outcomes are associated with less severe impacts.

Table 3
Cross-Tabulations of Observed and Expected Frequencies and
Calculated Standardized Residuals of Fetal Outcome by Impact Severity

Crash Severity p=0.003	Fetal Outcomes			
	No Problems	Minor Problems	Major Problems	Fetal Loss
Minor				
Observed	16.0	4.0	3.0	1.0
Expected	11.4	3.4	4.6	4.6
Std. residual	1.4	0.3	-0.7	-1.7
Moderate				
Observed	4.0	2.0	2.0	2.0
Expected	4.8	1.4	1.9	1.9
Std. residual	-0.3	0.5	0.1	0.1
Severe				
Observed	0.0	0.0	3.0	5.0
Expected	3.8	1.1	1.5	1.5
Std. residual	-2.0	-1.1	1.2	2.8

Table 4 lists the observed and expected values of fetal outcome by restraint usage, plus the calculated standardized residuals. For this analysis, the four improper restraint cases were excluded because of their small frequency. The differences in fetal outcome among the remaining restraint categories are significant (p=0.032), with unrestrained occupants having fewer good or minor-problem outcomes and more major problems than expected.

Table 4
Cross-Tabulations of Observed and Expected Frequencies and
Calculated Standardized Residuals of Fetal Outcome by Restraint Usage

Restraint Use p=0.032	Fetal Outcomes			
	No Problems	Minor Problems	Major Problems	Fetal Loss
None				
Observed	2.0	0.0	4.0	2.0
Expected	4.0	1.1	1.5	1.5
Std. residual	-1.0	-1.0	2.1	0.4
3-point belt				
Observed	10.0	3.0	0.0	5.0
Expected	9.0	2.4	3.3	3.3
Std. residual	0.3	0.4	-1.8	0.9
3-point belt and airbag				
Observed	7.0	2.0	3.0	0.0
Expected	6.0	1.6	2.2	2.2
Std. residual	0.4	0.3	0.5	-1.5

Table 5 isolates the cases involving proper use of three-point belts, with and without airbags. A comparison of fetal outcome for belt-only versus belt-and-airbag cases shows that they both have close to the expected number of good and minor outcomes. However, the three-point-belt-only cases have more deaths and fewer major problems than expected, while the three-point-belt-and-airbag cases have fewer deaths and more major problems than expected ($p=0.049$).

Table 5
Cross-Tabulations of Observed and Expected Frequencies and Calculated Standardized Residuals of Fetal Outcome by Proper Restraint Usage With and Without Airbags

Restraint Use $p=0.049$	Fetal Outcomes			
	No problems	Minor problems	Major Problems	Fetal Loss
3-point belt				
Observed	10.0	3.0	0.0	5.0
Expected	10.2	3.0	1.8	3.0
Std. residual	-0.1	0.0	-1.3	1.2
3-point belt and airbag				
Observed	7.0	2.0	3.0	0.0
Expected	6.8	2.0	1.2	2.0
Std. residual	0.1	0.0	1.6	-1.4

In another analysis, the restraint categories were first reduced to properly restrained (three-point belt with or without airbag) or improperly restrained (unrestrained, belt misuse, airbag only). The results shown in Table 6 are marginally significant ($p=0.07$), with proper restraints having fewer major complications than expected, and improper restraints having fewer no-problem cases and more major complications than expected statistically.

Table 6
Cross-Tabulations of Observed and Expected Frequencies and Calculated Standardized Residuals of Fetal Outcome by Proper and Improper Restraint Usage

Restraint Use $p=0.070$	Fetal Outcomes			
	No problems	Minor problems	Major Problems	Fetal Loss
Improperly Restrained/Unrestrained				
Observed	3.0	1.0	5.0	3.0
Expected	5.7	1.7	2.3	2.3
Std. residual	-1.1	-0.5	1.8	0.5
Properly Restrained				
Observed	17.0	5.0	3.0	5.0
Expected	14.3	4.3	5.7	5.7
Std. residual	0.7	0.3	-1.1	-0.3

It was hypothesized that fetal outcome might be affected by an interaction between restraint usage and impact severity (i.e., restraint effectiveness may be a function of crash severity, or restraint use might ameliorate the effects of impact severity of fetal outcome.) A three-way table was constructed to test this hypothesis, and several models were considered to account for the pattern of cell counts. Restraint categories used for this analysis are unrestrained, three-point belt, and three-point belt and airbag. Fetal outcome groups used are good/minor versus major/death. The results show little or no interaction between restraint usage and impact severity; crash severity still dominates the fetal outcome compared to restraint use.

Figure 21 graphically shows the distribution of all cases from this study according to impact severity and maternal restraint. The symbols in the bars indicate cases where the fetal outcome was a major complication or a fetal loss. An underlined symbol indicates that maternal death also occurred.

All of the severe crashes had poor fetal outcomes regardless of maternal restraint. In the moderate crashes, a fetal loss resulted from maternal death to the one unrestrained occupant. Two of the six women wearing three-point belts with deploying airbags in moderate crashes experienced major fetal complications. One of four pregnant occupants wearing a three-point belt (without an airbag deployment) in moderate crashes suffered a fetal loss. Of the twenty-four minor impacts, only one in each restraint category experienced an adverse fetal outcome.

Case Distribution

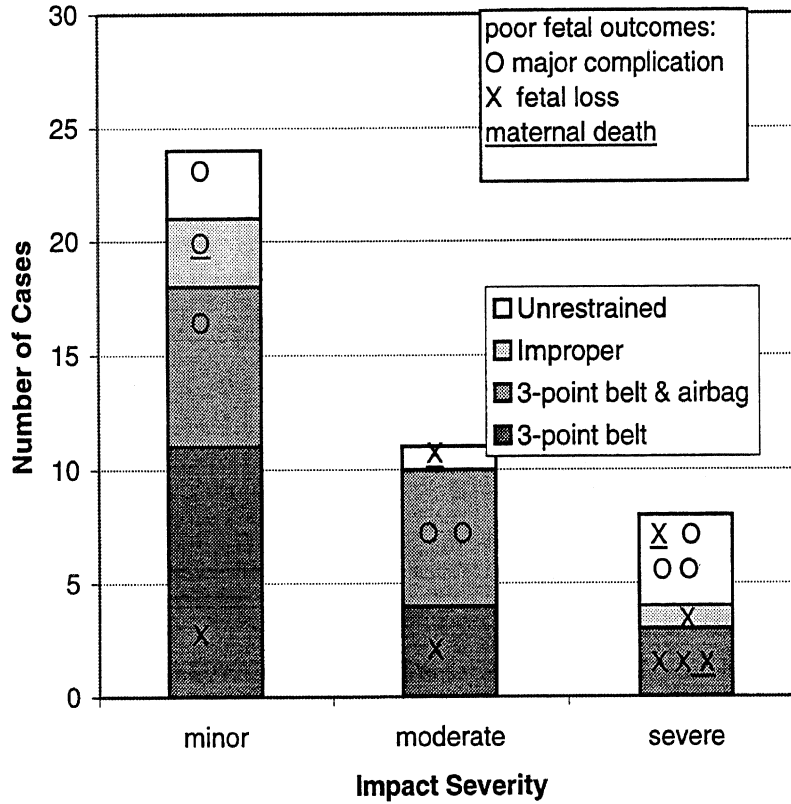


Figure 21. Distribution of maternal restraint type by impact severity with indication of adverse fetal outcomes and maternal death.

The results shown in the previous graph are replotted in Figure 22 to illustrate better how negative fetal outcomes vary with restraint usage. Five out of eighteen women wearing three-point belts suffered a fetal loss, but three of these were in severe crashes and one was in a moderate crash. No fetal losses occurred to thirteen women using three-point belts and an airbag, but three cases of major fetal complications occurred. Two cases of improper restraint led to adverse fetal outcomes, while the other two (restrained by airbag only in minor crashes) had successful fetal outcomes. For the eight unrestrained pregnant women, all five involved in severe or moderate crashes had adverse fetal outcomes, as did one unrestrained woman in a minor crash.

Case Distribution

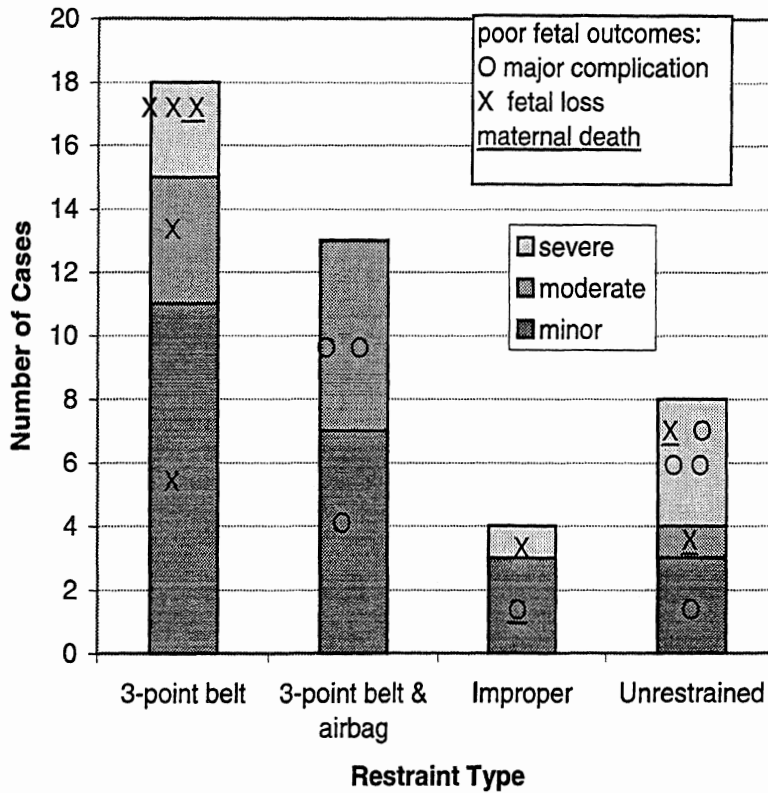


Figure 22. Distribution of impact severity by maternal restraint type with indication of adverse fetal outcomes and maternal death.

5.1.3 Impact Direction and Occupant Seating Position

Table 7 shows the observed and expected values of fetal outcome by impact direction, plus the standardized residuals. In this study, impact direction does not have a statistically significant effect on fetal outcome ($p=0.649$). The observed and expected counts are close for all combinations of impact direction and fetal outcome. Between 40% and 50% of the cases in each direction have adverse fetal outcomes.

Table 7
 Cross-Tabulations of Observed and Expected Frequencies and
 Calculated Standardized Residuals of Fetal Outcome by Impact Direction

Impact Direction p=0.649	Fetal Outcomes			
	No Problems	Minor Problems	Major Problems	Fetal Loss
Front				
Observed	13.0	5.0	5.0	4.0
Expected	12.9	3.9	5.1	5.1
Std. residual	0.0	0.6	-0.1	-0.5
Side				
Observed	5.0	0.0	1.0	3.0
Expected	4.3	1.3	1.7	1.7
Std. residual	0.3	-1.1	-0.5	1.0
Rear				
Observed	2.0	1.0	2.0	1.0
Expected	2.9	0.9	1.1	1.1
Std. residual	-0.5	0.2	0.8	-0.1

When all cases are considered, occupant position has a significant effect on fetal outcome (p=0.033). However, as seen in Table 8, the trends in fetal outcome with seating position are not clear. Drivers have more good outcomes than expected, front passengers have more minor and major complications than expected, and rear passengers have more major complications than expected. When the deaths and major complications are grouped together, about 40% of both the drivers and front passengers have negative fetal outcomes.

Table 8
 Cross-Tabulations of Observed and Expected Frequencies and
 Calculated Standardized Residuals of Fetal Outcome by Occupant Seating Position

Occupant Position p=0.033	Fetal Outcomes			
	No Problems	Minor Problems	Major Problems	Fetal Loss
Driver				
Observed	16.0	2.0	2.0	6.0
Expected	12.4	3.7	5.0	5.0
Std. residual	1.0	-0.9	-1.3	0.5
Front Passenger				
Observed	3.0	4.0	4.0	2.0
Expected	6.2	1.9	2.5	2.5
Std. residual	-1.3	1.6	1.0	-0.3
Rear Passenger				
Observed	1.0	0.0	2.0	0.0
Expected	1.4	0.4	0.6	0.6
Std. residual	-0.4	-0.7	1.9	-0.8

Figure 23 graphically shows the distribution of cases by impact direction and occupant seating position. Designations for adverse fetal outcomes and maternal deaths in each subgroup are included as well. For the frontal impacts, eight of seventeen drivers, two of eight front passengers, and one of two rear passengers experienced adverse fetal outcomes. One of five drivers in side impacts had both maternal and fetal loss; three of five front passengers involved in side impact crashes also had adverse fetal outcomes. For the six rear impacts, the one rear passenger and the one front passenger had major complications; one of four drivers sustained a fetal loss.

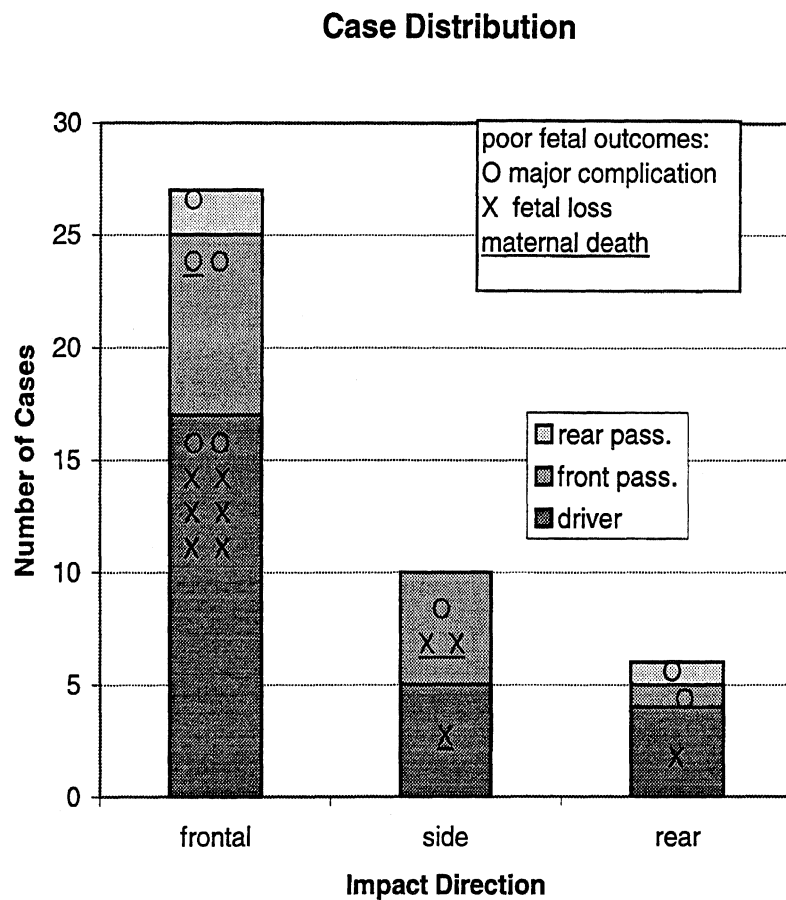


Figure 23. Distribution of pregnant occupant position by impact direction with indication of adverse fetal outcomes and maternal death.

5.1.4 Maternal Injury and Gestational Age

As shown in Table 9, maternal injury has a statistically significant effect on fetal outcome ($p=0.004$), with the standardized residuals indicating that more serious fetal outcomes are generally associated with more severe maternal injury. Pregnant women without injury have fewer major complications than expected, while women with minor injuries have fewer fetal losses than expected statistically. Pregnant occupants who were moderately injured have fewer no-problem cases and more major complications than expected.

Pregnant women who were fatally injured have fewer no-problem instances and more fetal losses than expected statistically.

Table 9
 Cross-Tabulations of Observed and Expected Frequencies and
 Calculated Standardized Residuals of Fetal Outcome by Maternal Injury

Maternal Injury p=0.004	Fetal Outcomes			
	No Problems	Minor Problems	Major Problems	Fetal Loss
None				
Observed	5.0	1.0	0.0	2.0
Expected	3.8	1.1	1.5	1.5
Std. residual	0.6	-0.1	-1.2	0.4
Minor				
Observed	14.0	5.0	4.0	1.0
Expected	11.4	3.4	4.6	4.6
Std. residual	0.8	0.8	-0.3	-1.7
Moderate				
Observed	1.0	0.0	3.0	2.0
Expected	2.9	0.9	1.1	1.1
Std. residual	-1.1	-0.9	1.7	0.8
Major				
Observed	0.0	0.0	1.0	0.0
Expected	0.5	0.1	0.2	0.2
Std. residual	-0.7	-0.4	1.9	-0.4
Death				
Observed	0.0	0.0	0.0	3.0
Expected	1.4	0.4	0.6	0.6
Std. residual	-1.2	-0.7	-0.8	3.2

Gestational age also has a statistically significant effect on fetal outcome ($p=0.033$). However, the standardized residuals shown in Table 10 do not show a regular pattern of increasing gestational age being more vulnerable to adverse fetal outcome.

Table 10
Cross-Tabulations of Observed and Expected Frequencies and
Calculated Standardized Residuals of Fetal Outcome by Gestational Age

Gestational Age $p=0.033$	Fetal Outcomes			
	No Problems	Minor Problems	Major Problems	Fetal loss
5 months				
Observed	5.0	0.0	0.0	1.0
Expected	2.9	0.9	1.1	1.1
Std. residual	1.3	-0.9	-1.1	-0.1
6 months				
Observed	6.0	0.0	1.0	3.0
Expected	4.8	1.4	1.9	1.9
Std. residual	0.6	-1.2	-0.7	0.8
7 months				
Observed	1.0	1.0	3.0	2.0
Expected	3.3	1.0	1.3	1.3
Std. residual	-1.3	0.0	1.4	0.6
8 months				
Observed	2.0	0.0	3.0	0.0
Expected	2.4	0.7	1.0	1.0
Std. residual	-0.2	-0.8	2.1	-1.0
9 months				
Observed	6.0	5.0	1.0	2.0
Expected	6.7	2.0	2.7	2.7
Std. residual	-0.3	2.1	-1.0	-0.4

Figure 24 graphically shows the distribution of case occupants by maternal injury and gestational age, with designations for adverse fetal outcomes in each subgroup. Nine of the ten cases where the maternal injury was moderate, major, or fatal had adverse fetal outcomes.

Case Distribution

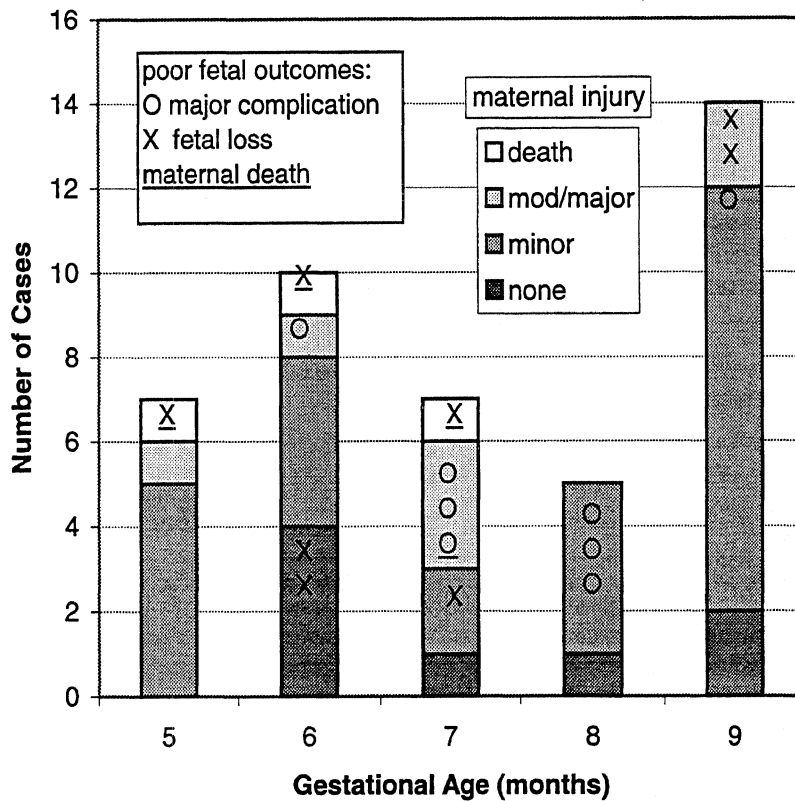


Figure 24. Distribution of maternal injuries by gestational age with indication of adverse fetal outcomes and maternal death.

5.1.5 Maternal Weight and Stature

When dividing the case subjects into groups by fetal outcome, the average maternal weight is the same for each group ($p=0.306$), but average maternal stature is different ($p=0.040$). Mean statures for the no problem, minor, major, and fetal loss outcomes are 164, 167, 157, and 167 cm, respectively. The mean statures in each group are similar except for the major problem category, indicating that shorter women are not necessarily more likely to have worse fetal outcomes when involved in crashes.

5.1.6 Summary

In Table 11, the cases are grouped by fetal outcome, and the severity, direction, and maternal restraint use for the cases in each group are listed. As can be more clearly seen, all the fetal losses occurred in severe or moderate impacts except for one minor rear crash where the exact cause of fetal death remains unknown.

Table 11
Summary of Crash Investigations by Fetal Outcome Category and Crash Factors

8 Fetal loss cases
2 severe frontal impacts with three-point belt
1 severe frontal impact with shoulder belt and airbag
1 moderate frontal impact with three-point belt
1 severe side impact with three-point belt (maternal death)
1 severe side impact with no restraint (maternal death)
1 moderate side impact with no restraint (maternal death)
1 minor rear impact with three-point belt
8 Major complication cases
1 severe frontal impact with no restraint
2 moderate frontal impacts with three-point belt and airbag
1 minor frontal impact with three-point belt and airbag
1 minor frontal impact with shoulder belt only (maternal death)
1 minor side impact with no restraint
2 severe rear impacts with no restraint
6 Minor complication cases
2 moderate frontal impacts with three-point belt
2 minor frontal impacts with three-point belt and airbag
1 minor frontal impact with airbag only
1 minor rear impact with three-point belt
21 No fetal problems
3 moderate frontal impacts with three-point belt and airbag
3 minor frontal impacts with three-point belt and airbag
4 minor frontal impacts with three-point belt
1 minor frontal impact with airbag only
2 minor frontal impacts with no restraint
1 moderate side impact three-point belt
1 moderate side impact airbag only
1 minor side impact three-point belt and airbag
3 minor side impacts with three-point belt
2 minor rear impacts with three-point belt

Of the eight cases with major complications, only one occurred in a minor crash to a properly belt- and airbag-restrained pregnant occupant. Two cases with major complications involved moderate impacts where the pregnant occupant was restrained by both a three-point belt and a deploying airbag. Four major-complication cases involved unrestrained occupants, of which three involved severe crashes and one a minor crash. The final major-complication case involved belt misuse (shoulder belt only) and maternal death in a minor crash.

The six cases with fetal outcomes of minor complications were all minor or moderate severity impacts. Five women were properly restrained with three-point belts, and two of

these were also restrained by an airbag. The sixth woman with minor fetal complications was only restrained by the airbag.

All twenty cases with good outcomes were of minor or moderate severity. In addition, proper maternal restraint was present in sixteen of the good outcome cases.

5.2 Risk Analysis

The preceding analysis indicates that crash severity is the most significant factor affecting fetal outcome following maternal involvement in a motor-vehicle crash. While the number of cases (43) is limited, this database provides the most extensive set of data to date on crashes involving pregnant occupants that include good estimates of crash severity. The following analysis uses these data to further examine the probability of poor fetal outcome as a function of crash severity.

In thirty-one cases, estimates of crash severity were determined using crush measurements from the vehicle in the WinSmash reconstruction program. In the remaining twelve cases, vehicle crush measurements were not available. Therefore, estimates of crash severity were made based on the judgment of experienced investigators after examining photos of the crash damage and police reports. These cases were originally assigned to an impact severity category of minor, moderate, or severe, and these classifications are believed to be fairly reasonable. However, a specific estimate of delta V was needed for the risk analysis calculations. The exact value of crash severity that was assigned to each case is based on crash investigators' extensive experience in relating visual damage to reconstructions using crush measurements. This group of twelve cases is referred to as the visual-estimate group; their effect on the risk calculations was examined.

The fetal outcomes were divided into two categories: (1) good outcomes and minor complications and (2) major complications and fetal losses. Using this binary outcome ranking, risk models were calculated using logistic regression routines in Statistical Package for the Social Sciences (SPSS).

Figure 25 shows the probability of fetal loss or major complication as a function of crash severity when all the cases are used. Symbols represent each case, with favorable outcomes assigned a zero value and adverse outcomes assigned a 1 on the ordinate scale. Error bars represent a 95% confidence interval. Figure 26 shows the results when only frontal impacts are included (n=27), and figure 27 shows the results when the twelve visual-estimate cases are excluded. Figure 28 shows an overlay of these three curves for easier comparison. Excluding the side and rear impacts does not significantly change the shape or position of the curve. Excluding the visual-estimate cases increases the crash severity for a 50% level of risk of adverse fetal outcome from 31.6 ± 8.7 to 38.2 ± 13.4 kph. When visual-estimate cases are excluded, the slope of the curve decreases (variance increases), such that at the lower range of crash severity, the probabilities of poor outcome are similar (10% risk corresponds to ~11 kph for all cases vs. ~14 kph when visual estimates are excluded). At the high end of crash severity, estimated probabilities

of poor outcome are higher when visual-estimate cases are included (80% risk at ~45 kph for all cases vs. ~54 kph without estimates.)

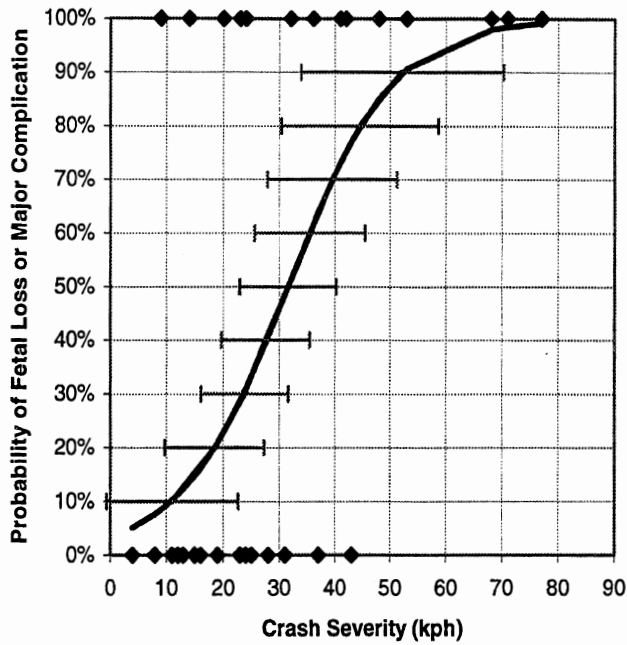


Figure 25. Risk of adverse fetal outcome by crash severity for all cases (n=43).

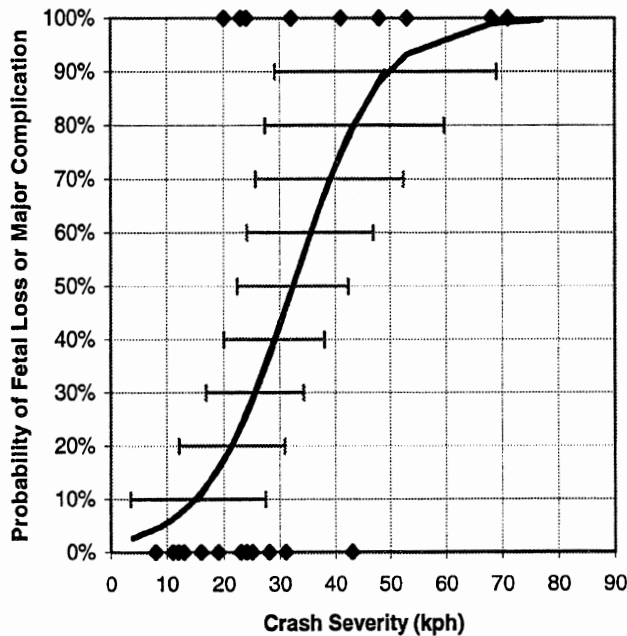


Figure 26. Risk of adverse fetal outcome by crash severity for frontal-impact cases (n=27).

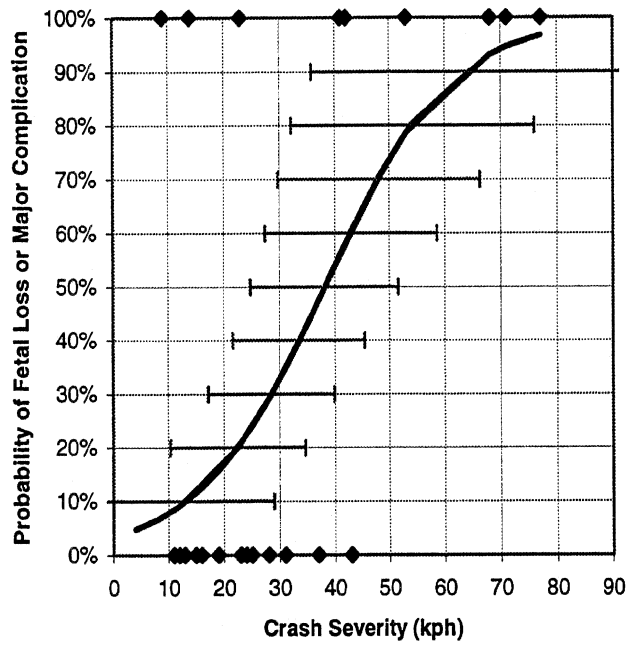


Figure 27. Risk of adverse fetal outcome by crash severity with visual-estimate cases excluded (n=31).

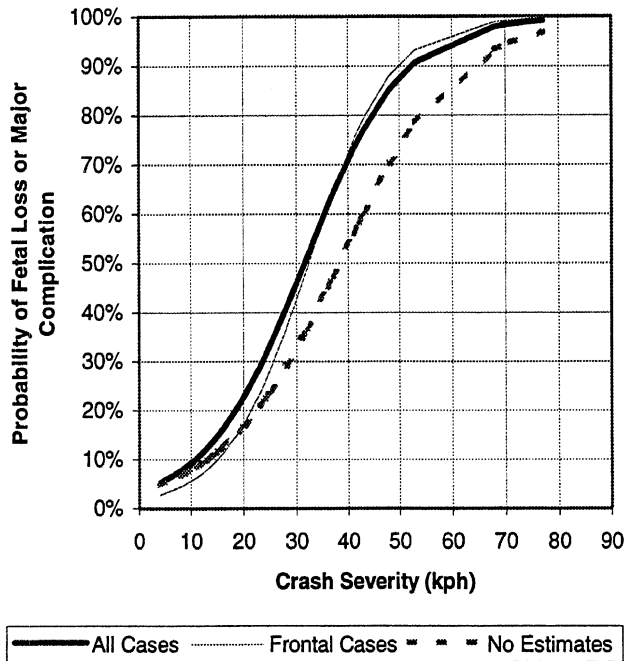


Figure 28. Comparison of risk curves for all cases, frontal crashes only, and all cases minus visual estimates.

Logistic regressions were also performed to compare the estimated risk curves for the properly restrained occupants (three-point belts or three-point belts and airbags) and improperly restrained occupants (unrestrained, airbag only, and shoulder belt only, with and without airbag.) Figure 29 illustrates the results for all properly restrained occupants, while Figure 30 shows the results for all improperly restrained occupants. Error bars indicate a 95% confidence interval. The analysis was also conducted excluding the cases with visual estimates of crash severity, and the results are shown in Figures 31 and 32. The error bars become quite large as the number of cases is reduced.

Figure 33 compares the four curves. The difference in the risk curves for the unrestrained occupants with and without the visual-estimate cases is small, as only two out of twelve cases with improperly restrained occupants involved visual estimates of crash severity. The curve for properly restrained occupants is more strongly affected by the cases with visual estimates of crash severity. However, both risk estimates for properly restrained pregnant occupants show a much higher level of crash severity associated with a particular level of risk compared to the unrestrained occupants. The estimated severity for a 50% risk of adverse fetal outcome for properly restrained pregnant occupants is 36.1 ± 11.7 kph, while it is only 15.8 ± 9.3 kph for unrestrained pregnant occupants.

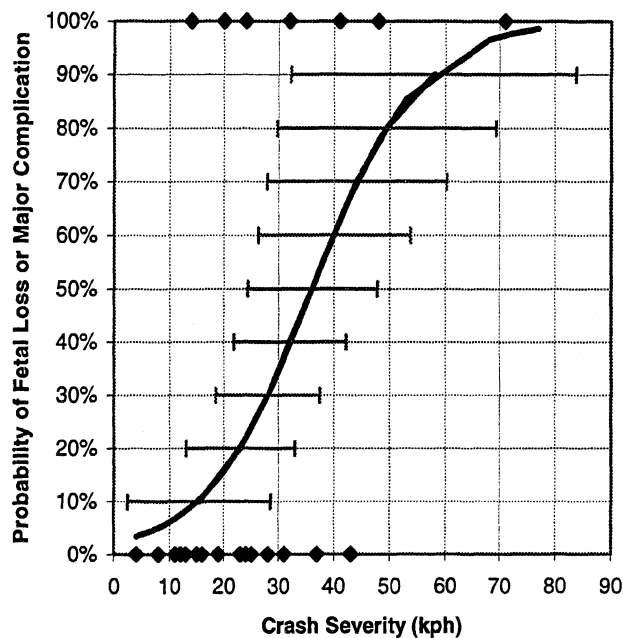


Figure 29. Risk of adverse fetal outcome by crash severity for properly restrained occupants (n=31).

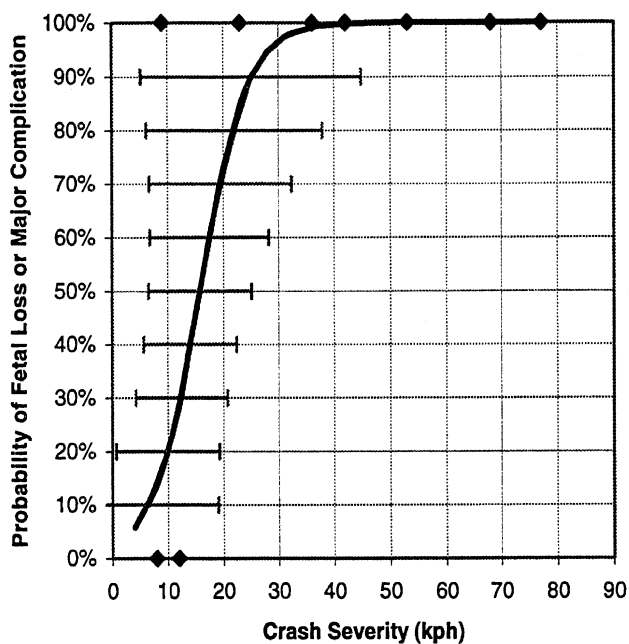


Figure 30. Risk of adverse fetal outcome by crash severity for improperly restrained and unrestrained occupants (n=12).

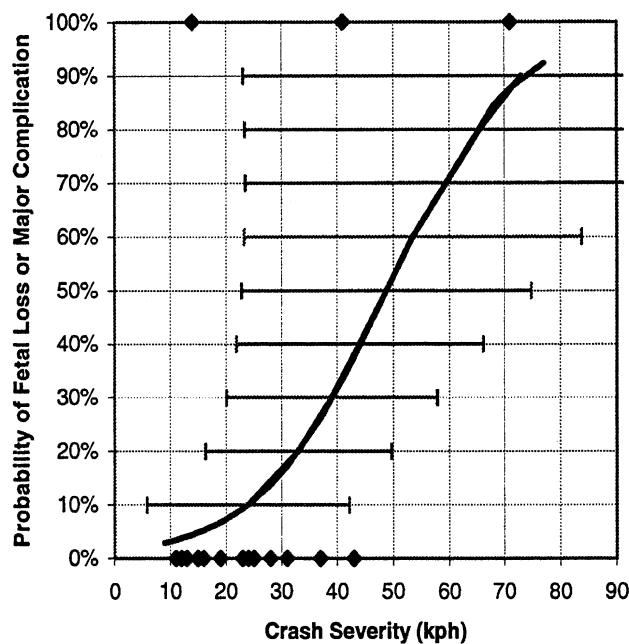


Figure 31. Risk of adverse fetal outcome by crash severity for properly restrained occupants with visual-estimate cases excluded (n=21).

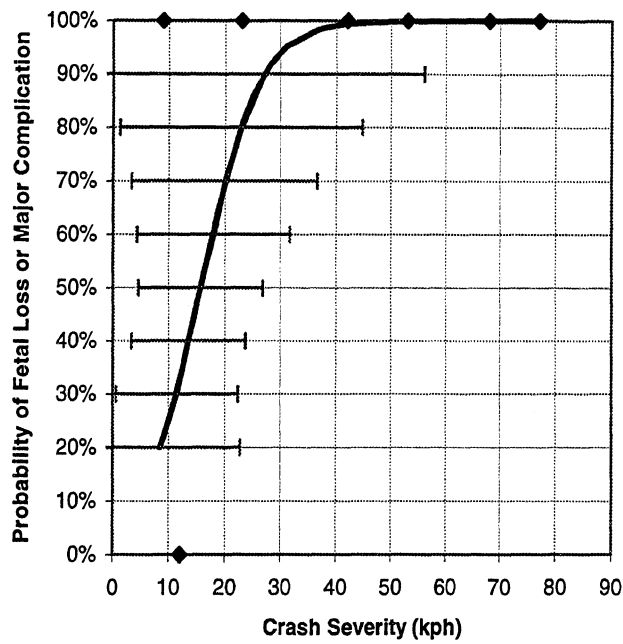


Figure 32. Risk of adverse fetal outcome for improperly restrained and unrestrained pregnant occupants, with visual-estimate cases excluded (n=10).

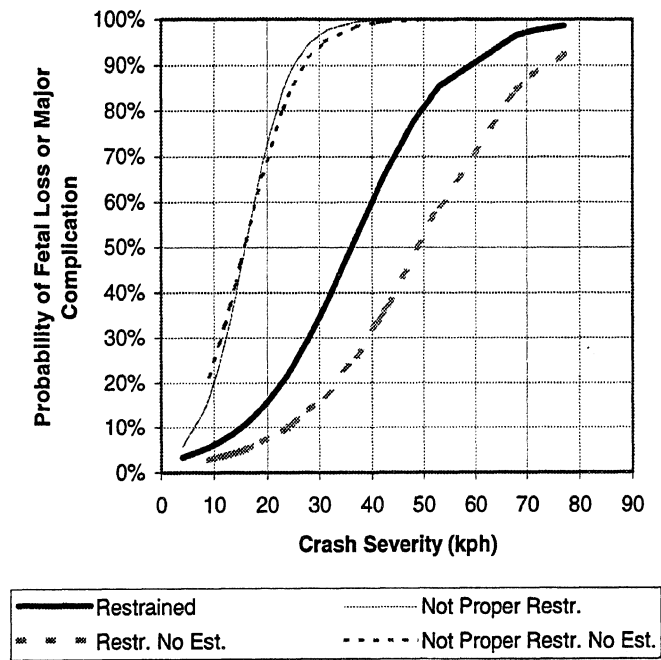


Figure 33. Comparison of risk curves for properly restrained and improperly restrained/unrestrained pregnant occupants.

5.3 Estimates of Annual Fetal Losses

As mentioned in the introduction, there is no direct way to estimate the number of fetal losses resulting from maternal involvement in motor-vehicle crashes. However, several different approaches for estimating the magnitude of the problem have been used with varying results as described below.

Pearlman (1997) estimated the annual number of fetal losses in motor-vehicle crashes using the following approximations. In the United States, there are about 4 million births per year. About 6 to 7% of pregnant women experience some sort of trauma during pregnancy. Of those traumas, about two-thirds result from involvement in motor-vehicle crashes. About 1 to 3% of pregnant women who suffer trauma in pregnancy have placental abruptions that lead to fetal losses. Multiplying these probabilities gives 1600 to 4800 fetal losses per year.

Another approach uses crash data and birth rates to estimate the number of pregnant women involved in crashes, and uses several variations to estimate fetal loss rates. The estimated numbers of pregnant women killed, injured, or involved in crashes are shown in Table 12. The U. S. female population is divided into four age groups from 15 to 44 years of age, encompassing most of the childbearing population. Using the population of females from census data and the number of births from National Center for Health Statistics (NCHS) data for each age group, the fraction of women in each age group that are pregnant was calculated; it excludes women who are pregnant and have a fetal loss. From *Traffic Safety Facts*, the number of women involved in vehicle-damage crashes each year by age group was determined, and divided into the estimated number of pregnant occupants who are killed, injured, and uninjured. To include only women at gestational ages of 20 to 40 weeks in the year, a factor of 20/52 is applied. The combination of these values provides estimates of the number of pregnant women of gestational ages 20 to 40 weeks who are involved in motor-vehicle crashes each year, where some vehicle damage has occurred.

Table 12
Estimation of Number of Pregnant Women in Crashes by Maternal Outcome

	Age Groups (years)*				Total
	15-19 or 16-20	20-24 or 21-24	25-34	35-44	
U.S. Population 11/98 (<i>census.gov</i>)	9478000	8666000	19232000	22395000	59771000
1996 Births (<i>cdc.gov</i>)	494272	951247	1982740	472473	3900732
Percentage pregnant	5.2%	11.0%	10.3%	2.1%	6.5%
<i>From 1996 Traffic Safety Facts</i>					
women killed	1725	919	1916	1713	6273
women injured	30100	164000	367000	297000	1129000
women uninjured**	956228	548243	1193475	1049804	3747750
total women in vehicle-damage crashes	1258953	713162	1562391	1348517	4883023
Number of pregnant women greater than 20 weeks gestational age (percentage pregnant * 20/52)					
pregnant women killed	35	39	76	14	163
pregnant women injured	6037	6924	14552	2410	29923
pregnant women uninjured	19180	23146	47324	8518	98168
pregnant women in vehicle-damage crashes	25251	30109	61952	10942	128255

*first age grouping used by census and CDC, second age grouping used in *Traffic Safety Facts*

**number of drivers reported explicitly; number of passengers estimated based on ratios of drivers and passengers killed or injured.

Different fetal loss rates (FLR) have been applied to these numbers in several different ways to estimate the fetal loss rate due to maternal involvement in motor-vehicle crashes during the second half of pregnancy. Results are shown in Table 6. First, the total number of women in vehicle-damage crashes is multiplied by 1 to 3%, which is the estimated proportion of women who suffer trauma in pregnancy and subsequently have placental abruptions that lead to fetal losses. As indicated in Table 13, this gives estimates of 1283 to 3848 fetal losses per year, which is similar to that estimated by Pearlman.

However, the 1 to 3% estimated FLR is based on studies in the literature of pregnant women admitted to hospitals, which may exclude those involved in crashes who were uninjured. The table therefore includes an estimate based on applying the 1 to 3% FLR to injured women, and assumes that all injured pregnant women are admitted to hospitals. In addition, a 100% FLR is applied to pregnant women killed in motor-vehicle crashes. This approach estimates 163 fetal losses resulting from maternal death, and 299 to 898 fetal losses from placental abruption to pregnant women injured in motor-vehicle crashes. This approach does not include fetal losses to women involved in motor-vehicle crashes who are not injured, which is expected to be a small number.

A review of the publications used to estimate the 1 to 3% overall FLR suggests that for noncatastrophic trauma, FLR is closer to 1%, while for catastrophic maternal trauma, the FLR ranges from 12 to 40%. Analysis was conducted of the 1996 NASS database, and

the proportion of injured women with ISS <20 was 99.4%. The group of injured women was split into groups of women with minor or serious injuries based on ISS score, and a FLR of 1% applied to the minor-injury group and 20% FLR to the serious-injury group. This calculation estimates 333 fetal losses to injured women (separated by minor and severe injuries), slightly higher than the number calculated by applying a 1% FLR to all women injured.

Table 6
Estimates of Fetal Losses

	Fraction of total in Table 5	FLR	Fetal Losses by Age Group				Total all age groups
			15-19 or 16-20	20-24 or 21-24	25-34	35-44	
All pregnant women in crashes		1%	253	301	620	109	1283
		3%	758	903	1859	328	3848
Pregnant women killed		100%	35	39	76	14	163
Pregnant women injured		1%	60	69	146	24	299
		3%	181	208	437	72	898
Women with ISS ≥ 20	0.6%	20%	7	8	17	3	
Women with ISS <20	99.4%	1%	60	69	145	24	
Total fetal losses to injured pregnant women			67	77	162	27	333
Women injured in severe crashes > 30 mph	1%	17%	10	12	25	4	
Women injured in moderate crashes 15-30 mph	26%	12.4%	195	223	469	78	
Women injured in minor crashes < 15 mph	72%	2.2%	96	110	231	38	
Total fetal losses to injured pregnant women			301	345	724	120	1490
Women injured in severe crashes > 30 mph	1%	42.5%	26	29	62	10	
Women injured in moderate crashes 15-30 mph	26%	31%	487	558	1173	194	
Women injured in minor crashes < 15 mph	72%	5.5%	239	274	576	95	
Total fetal losses to injured pregnant women			751	862	1811	300	3724

Fetal losses to pregnant women injured in motor-vehicle crashes were estimated a fourth way by grouping the injured women according to crash severity and using different FLR for each group. The 1996 NASS database was analyzed, and the severity distribution for crashes with women of childbearing age was determined. For cases with known crash severity, 1% were > 30 mph delta V, 26% were 15-30 mph delta V, and 72% were < 15 mph delta V. From the injury risk curves developed in section 5.2, risks of adverse outcome at 12 kph, 36 kph, and 48 kph are estimated as 0.11, 0.62, and 0.85, respectively. This calculation includes both fetal losses and major complications, so the risk of fetal loss was considered to be a fraction of these risks. Twenty percent and 50% were arbitrarily selected, and the FLR used are shown in the FLR column of Table 13. The group of injured pregnant women was divided according to the crash severity

percentages, and two sets of FLR derived from the risk of adverse fetal outcome curves were applied. This approach led to an estimated 1490 to 3724 fetal losses per year from motor-vehicle trauma.

6.0 SUMMARY AND DISCUSSION

Eighty-seven crashes involving pregnant occupants were identified in this study, resulting in twenty-seven in-depth investigations. For these cases, detailed injury data were obtained with subject consent, the case vehicle was carefully inspected, measured, and photographed, and a reconstruction analysis of the crash was performed. The case occupant was also interviewed and, in a few cases, she was photographed and measured in the case vehicle to obtain more accurate information on her position relative to the vehicle interior and the restraint systems.

In fifteen of the cases, only minor investigations were conducted because the vehicle was unavailable or undamaged, or because of a lack of medical records or maternal injuries. Forty-five of the identified cases were excluded from the study because the subject did not agree to participate, or because other criteria for an investigation were not met (e.g., the occupant was less than 20 weeks pregnant).

The pregnant occupant was the driver in twenty-six cases, a rear passenger in three cases, and the right-front passenger in fourteen cases. Eight occupants were unrestrained, eighteen were restrained by a three-point belt, thirteen were restrained by a three-point belt plus an airbag, two were restrained only by an airbag, one was restrained only by a shoulder belt, and one was restrained by a shoulder belt plus an airbag. The crashes are divided into three crash severity levels of severe (eight cases), moderate (eleven cases), and minor (twenty-four cases). Twenty-seven crashes were frontal impacts, ten were side impacts, and six were rear impacts. Eight crashes resulted in fetal loss, eight crashes resulted in a placental abruption, a direct fetal injury, or extremely premature delivery without fetal loss, six crashes resulted in minor fetal complications, and twenty-one crashes resulted in good fetal outcomes.

For the twenty-seven frontal impacts, four were classified as severe and led to fetal loss in three cases and DFI in the fourth. The case with DFI involved an unrestrained pregnant rear passenger. One of the fetal losses was to a driver restrained by an airbag and shoulder belt, while the other two were to drivers restrained by three-point belts.

Eight of the frontal impacts were of moderate severity. The three moderate cases with good fetal outcomes involved two drivers and one right-front passenger restrained by three-point belts and airbags. Two other moderate cases with three-point belts and airbags (one driver, one right-front passenger) resulted in major fetal complications. The remaining three moderate frontal impacts involved pregnant occupants wearing three-point belts, and resulted in two minor fetal complications to front passengers and one fetal loss to a driver.

Two of the twenty-four minor frontal impacts were to unbelted pregnant women and had good fetal outcomes. One was a driver and one was a right-front passenger. In six of the minor frontal impacts, the occupant was restrained by both a three-point belt and an airbag. Three of these were drivers and had good fetal outcomes, two were front passengers and had minor complications, and one was a driver that had major

complications. Four of the minor frontal impacts involved an occupant restrained by a three-point belt and all had good fetal outcomes. In three of these cases, the pregnant occupant was the driver, and in the fourth case she was a rear passenger. Two pregnant drivers involved in minor frontal impacts were restrained only by an airbag. One of these had a good outcome and one had minor complications. In the remaining minor frontal crash, the pregnant right-front passenger was restrained only by a shoulder belt; maternal death and major fetal complications resulted.

Two of the side impacts were severe and resulted in maternal and fetal death. One of these women was an unrestrained driver and the other was a front passenger who was wearing the three-point belt. Three side impacts were moderate in severity. One, in which the pregnant front passenger was unrestrained, led to both maternal and fetal death. The other two moderate side impacts had good fetal outcomes, and involved a driver restrained by a three-point belt and a right-front passenger restrained by an airbag. Five of the side impacts were minor. The only unrestrained pregnant woman, a right-front passenger, had major fetal complications. Two drivers and one right-front passenger were restrained by a three-point belt and had good fetal outcomes, as did the pregnant driver restrained by a three-point belt and an airbag.

Of the six rear impacts, two involved severe impacts to unrestrained pregnant passengers (one in front and one in the rear seat) that resulted in major fetal complications. One minor rear impact resulted in a fetal loss to a driver restrained by a three-point belt. The other three minor rear impacts were to drivers restrained by three-point belts and led to one minor fetal complication and two good fetal outcomes.

The cases in this study include most of the injuries and complications described in the literature that are sustained by pregnant women in crashes. Eight cases resulted in fetal loss, three because of maternal death (cases 2, 205, 212). Case 2 also resulted in a fetal arm fracture. Two other fetal losses were a result of placental abruption (10, 214), two were for unknown reasons (21, 206), and one fetus died 1 hour after a very early delivery necessitated by a placental abruption.

Four cases had placental abruptions with fetal survival, although all of them resulted in premature births. Of these, case 6 also involved uterine lacerations, and the infant suffered from neonatal respiratory distress syndrome. In case 216, the infant also suffered from respiratory distress and had a direct fetal head injury and apnea. In case 207, both pregnant occupants had placental abruptions and early deliveries, and one infant may have sustained a head injury.

In three other cases (2, 13, 26) the infant suffered a head injury in utero that might have long-term effects on the child's health. The UMTRI cases also include a very unusual instance of fetal survival after maternal death (case 22), in which the neonate experienced typical complications from premature delivery.

Six cases led to minor complications. In five cases, the pregnant occupant had contractions immediately after the crash, two of which required medical intervention to stop. In the sixth minor complication case, delivery occurred within 48 hours of the

crash, but the pregnancy was advanced enough for the birth not to be considered premature.

The data from this study were used to estimate the risk of adverse fetal outcome as a function of crash severity. The risk curves generated from the analysis are generally consistent with estimated fetal loss rates reported in the literature. Pearlman (1997) summarized the literature on estimated fetal loss rates resulting from placental abruption due to maternal involvement in motor-vehicle crashes. Rates were from 1 to 5% in minor severity crashes, and 30 to 50% in severe crashes. These values focus on only fetal losses resulting from placental abruptions, while the injury risk curves presented in this study include fetal losses from all causes plus major fetal complications.

When the UMTRI pregnancy crash database is compared to a compilation of 100 cases from the literature, some major differences are apparent. The UMTRI study includes 19% unrestrained, 9% improperly restrained, and 72% properly restrained pregnant occupants. Overall, the cases from the literature report 55% unrestrained, 11% improperly restrained, and 34% restrained. The cases from the literature have a much less favorable distribution of restraint use, partly because many cases are from times when restraint use was much less prevalent. In addition, case studies in the literature tend to focus on highly adverse outcomes, which can be expected to occur more frequently to unrestrained or improperly restrained pregnant women.

The distribution of fetal outcomes between the UMTRI cases and cases from the literature also reflects the concentration in the literature on poor fetal outcomes. In the UMTRI study, 18.6% of the cases resulted in fetal loss. In the cases from the literature, 80% had fetal loss. Both of these studies had fetal loss rates much higher than that seen clinically in pregnant trauma patients and cannot be considered representative of results for the population.

However, the UMTRI study documents for the first time a significant number of positive fetal outcomes. It also includes a proportion of properly restrained pregnant occupants that is consistent with restraint usage rates seen in today's U. S. population. The restraint usage also encompasses more airbag deployments with pregnant women than previously documented. Another important feature of the UMTRI study is its inclusion of crash severity estimates, which turned out to be the most significant factor associated with fetal outcome. Case studies in the literature sometimes suggest the restraint as the cause of the adverse fetal outcome, but often mention clues to indicate that the crash was very severe. In many of these instances, it may be the crash severity that is the cause of poor fetal outcome rather than restraint use, and an unbelted pregnant woman in the same conditions would have suffered the same poor fetal outcome and a worse outcome for herself. Cases that claim restraints cause injury cannot be substantiated unless there are reasonable estimates of crash severity.

A particular interest of this study was to document airbag performance and effectiveness for pregnant occupants, since widespread use of this restraint is relatively recent. When comparing the fetal outcomes of women restrained by three-point belts and three-point belts and airbags, the number of good and minor complication fetal outcomes were close

to the statistically expected number for this sample. The pregnant women restrained by three-point belts had no major complications and five fetal deaths, while the women restrained by three-point belts and airbags had three major complications and no fetal deaths. While this analysis is limited by the small number of cases, it is theorized that the additional restraint of an airbag may have improved the fetal outcome from a loss to a major complication in these three cases. In addition, while the use of only an airbag is not considered properly restrained in this study because three-point belt use is recommended for pregnant women, the two cases of airbag-only restraint did not have negative outcomes.

Of thirty-one properly restrained occupants, eight (25.8%) experienced fetal loss or major complications. Of twelve improperly restrained or unrestrained occupants, eight (66.7%) had fetal loss or major complications. These results clearly support the current recommendation for pregnant women to properly wear three-point belts.

7.0 CONCLUSIONS

This study of pregnant women involved in crashes has led to the following observations and conclusions regarding the database in this study:

- Crash severity has the most significant effect on fetal outcome, with more severe crashes associated with more adverse fetal outcomes. Severe crashes lead to negative fetal outcomes regardless of maternal restraint or impact direction.
- More severe maternal injury was associated with more adverse fetal outcomes. The three cases of maternal death to unrestrained or improperly restrained women supports previous observations that protecting the mother is the first step in protecting the fetus.
- Proper restraint use had a statistically significant positive effect on fetal outcome.
- Impact direction did not have an effect on fetal outcome.
- Fetal outcome varied statistically with occupant position, but adverse fetal outcomes were not clearly associated with a particular position.
- Fetal outcome varied statistically with gestational age, but adverse fetal outcomes were not clearly associated with a particular gestational age.
- Maternal weight and maternal height did not correlate with fetal outcome.
- The majority of pregnant women properly wearing a three-point belt, with or without an airbag, generally had good fetal and maternal outcomes for lower severity crashes.
- Though the number of cases is limited, airbags used in conjunction with three-point belts appear to have a positive effect on fetal outcome compared to three-point belt use only.
- The risk of adverse fetal outcome at a particular crash severity level is higher for improperly restrained or unrestrained pregnant women compared to properly restrained pregnant women.

8.0 ACKNOWLEDGMENTS

The work covered by this report was financed by General Motors (GM) pursuant to an agreement between GM and the U.S. Department of Transportation. The authors would like to acknowledge Joel MacWilliams, Tim Compton, and Dale Halloway, who assisted with some of the investigations. They would also like to thank the crash investigation teams at the University of California San Diego and the Miami Trauma Center, and Richard Stalnaker, who provided information on some of the cases. Statistical guidance provided by Carol Flannagan is greatly appreciated. Patricia Reis should be recognized for assisting with the analysis of the medical records.

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Appendix A

Table of Case Studies from the Literature

The first column in Table A.1 lists a case number for reference in this paper. The second column lists the occupant position in the vehicle, impact direction, and impact severity if the data are available. Some sources from the literature only reported the occupant as being a passenger and did not indicate whether the location was the front or rear seat. The type of crash is classified as front, side, rear, rollover, or multiple impact. Information on whether the crash was a near- or far-side impact is usually not available. Crash severity is based on the following divisions: minor is less than 24 km/h (15 mph) change in velocity, moderate is 24 to 48 km/h (15 to 30 mph), and severe is greater than 48 km/h (30 mph). The crash-severity estimates were made by the occupants or physicians and probably relate more to the speed of travel before the crash rather than actual change in velocity. In the majority of cases in Table A.1, no estimate of crash severity is made.

The third column in Table A.1 lists the restraint conditions for the pregnant occupant. Some of the sources report use of a belt restraint, but do not clarify whether a lap belt or three-point belt was used, or if the belt was positioned properly; these cases are listed only as restrained. If the pregnant occupant reported wearing the lap belt portion of the belt across the bulge of her pregnant abdomen (crossing near the umbilicus) rather than below it, belt use is documented as improper. The fourth column gives gestational age in weeks, with 40 weeks considered full term. In the text of this report, gestational ages are grouped into four-week increments and referred to as the fifth month (20-23 weeks), sixth month (24-27 weeks), seventh month (28-31 weeks), eighth month (32-35 weeks), or ninth month (36 weeks or more) of pregnancy.

Maternal injuries are given in the fifth column and are described in two ways. The first term describes the overall severity of injuries that are not related to pregnancy. The categories are none, minor, moderate, and major. These descriptions are estimates of the maximum AIS scores (ignoring uterine or placenta injuries), with minor injuries corresponding to MAIS 1 or 2, moderate, MAIS 3 or 4, and major, MAIS 5 or 6. The remainder of the maternal injury description describes the injuries to the uterus and placenta. Pelvic fractures are specifically noted in the maternal injury column as they are suspected to increase the probability of injury to the pregnant abdomen and fetus. Maternal death is indicated by *italic type*.

The sixth column describes the fetal outcome, specifically listing any direct injuries or complications. Fetal survival is indicated by *italic type*.

The final column lists the source of the case data. The source lists the authors and year of publication, plus a case number if the source presented more than one case.

No.	Occupant Position Impact Direction Impact Severity	Restraint	Gest Age (wk)	Maternal Injuries (italics indicate maternal fatality)	Fetal Outcome (italics indicate fetal survival)	Case Source
1	front passenger front impact severe crash	none	24	<i>major</i>	stillborn	Agran et al. (1986) Case 1
2	rear passenger rollover severe crash	none	23	moderate, placental abruption	stillborn	Agran et al. (1986) Case 2
3	driver front impact moderate crash	none	23	minor, placental abruption	stillborn	Agran et al. (1986) Case 3
4	driver front impact severe crash	none	26	minor, placental abruption	stillborn	Agran et al. (1986) Case 4
5	driver front impact	none	30	minor, placental abruption	stillborn	Agran et al. (1986) Case 5
6	driver front impact moderate crash	none	34	minor, placental abruption, uterine rupture	stillborn	Agran et al. (1986) Case 6
7	driver front impact	none	35	moderate, placental abruption & laceration	skull fracture	Agran et al. (1986) Case 7
8	driver front impact moderate crash	none	38	minor, placental abruption	stillborn	Agran et al. (1986) Case 8
9	driver front impact	none	39	minor, placental abruption	stillborn	Agran et al. (1986) Case 9
10	rear passenger	improper lap belt	27	minor, placental abruption, uterine laceration	brain hemorrhage, transected aorta & spine, lacerated liver & kidney	Astarita and Feldman (1997)
11	driver front impact severe crash	restrained	23	minor	<i>brain damage</i>	Baethman et al. (1996) Case 2
12	passenger side impact	restrained	28	minor, pelvic fracture	<i>brain damage</i>	Baethman et al. (1996) Case 3
13	front passenger severe crash	none	37	none	<i>contractions, emergency C/S, brain damage</i>	Baethman et al. (1996) Case 9
14	front passenger side impact severe crash	restrained	28	moderate	stillborn	Bowden et al. (1997)
15	front passenger side impact	none	37	moderate, pelvic fx, partial placental abruption	<i>emergency C/S, skull fracture, brain hemorrhages, apnea</i>	Bowdler et al. (1987)
16	front passenger front impact severe crash	lap belt	37	none, partial placental abruption	<i>emergency C/S, seizures, renal failure</i>	Chetcuti and Levene (1987)
17	driver front impact severe crash	none	37	moderate, placental laceration	stillborn	Civil et al. (1988)
18	driver front impact	none	39	moderate, partial placental abruption	liver, adrenal, and kidney contusions, seizures	Connor and Curran (1976)

No.	Occupant Position Impact Direction Impact Severity	Restraint	Gest Age (wk)	Maternal Injuries (italics indicate maternal fatality)	Fetal Outcome (italics indicate fetal survival)	Case Source
19	driver front impact minor crash	none	37	minor, placental damage	skull fracture, brain hemorrhage	Cumming and Wren (1978)
20	driver side impact	none	24	minor, pelvic fx, placental abruption, uterine rupture	stillborn	Dash and Leptin (1991)
21	rear passenger front impact severe crash	none	30	moderate, pelvic fx, placental abruption, uterine rupture	stillborn	Dittrich (1996)
22	driver side impact severe crash	none	32	<i>moderate, pelvic fx</i>	skull fracture	Evrard et al. (1989)
23	front passenger front impact severe crash	3-pt belt	30	minor	head, thorax, and abdomen hemorrhages	Fakhoury and Gibson (1986)
24	driver front impact	restrained	30	moderate	brain hematomas	Ford and Picker (1989)
25	driver front impact severe crash	3-pt belt	27	none	cerebral hemorrhage, hepatic hemorrhage, hemoperitoneum	Fries and Hankins (1989)
26	driver rear impact	none	39	minor, uterine laceration	<i>emergency delivery, seizures, respiratory distress</i>	Galle and Anderson (1979)
27	front passenger	3-pt belt	36	moderate, placental laceration	head contusions	Griffiths et al. (1991) Case 1
28	front passenger	3-pt belt	31	minor, placental damage	stillborn	Griffiths et al. (1991) Case 2
29	driver side impact	improper 3-pt belt	28	minor, placental abruption, uterine rupture	brain hemorrhages	Handel (1978)
30	driver front impact moderate crash	3-pt belt	22	minor, placental abruption, uterine rupture	stillborn	Harrison et al. (1996)
31	rear passenger rollover	none	41	minor, partial placental abruption	<i>emergency C/S, skull fracture</i>	Hartl and Ko (1996)
32	driver front impact	none	20	minor, pelvic fx, uterine laceration	stillborn	Heitzman and Markarian (1970)
33	driver front impact	none	29	moderate, partial placental abruption, uterine laceration	<i>emergency C/S, premature</i>	Kettel et al. (1988) Case 2
34	front passenger	none	34	none, partial placental abruption	<i>emergency C/S, premature</i>	Kettel et al. (1988) Case 3
35	driver front impact severe crash	none	25	minor	<i>contractions stopped w/o intervention, brain damage</i>	Knuppel et al. (1994)
36	driver front impact	none	34	moderate, pelvic fx, placental abruption, uterine rupture	skull fracture	Landers et al. (1989)
37	driver front impact severe crash	none	28	minor, placental abruption	<i>emergency C/S, premature, respiratory distress</i>	Lavin and Miodovnik (1981)
38	front passenger severe crash	restrained	?	none, pelvic fx	<i>no complications</i>	Levin and Edson (1994)
39	driver side impact	3-pt belt	39	moderate, pelvic fx	<i>emergency C/S, brain contusion, seizures</i>	Matthews and Hammersly (1997)
40	front passenger front crash	improper 3-pt belt	25	minor, placental abruption, uterine laceration	stillborn	Matthews (1975)

No.	Occupant Position Impact Direction Impact Severity	Restraint	Gest Age (wk)	Maternal Injuries (italics indicate maternal fatality)	Fetal Outcome (italics indicate fetal survival)	Case Source
41	front passenger front impact	improper lap belt	20	none, uterine transection	transection	McCormick (1968)
42	driver front impact	none	41	minor, partial placental abruption	stillborn	Nichols and Weedn (1986)
43	driver	none	21	major	<i>premature delivery at 34 weeks</i>	Nunn et al. (1996)
44	front passenger front impact	none	38	minor	amniotic membrane rupture	Parkinson (1964) Case 3
45	driver multiple impact	3-pt belt	32	moderate, pelvic fx, placental abruption	stillborn	Pearlman et al. (1988)
46	driver side impact	none	36	none	stillborn	Pepperell et al. Case 1 (1977)
47	driver front impact	none	39	none, placental laceration	stillborn	Pepperell et al. (1977) Case 2
48	driver front impact	none	30	none	skull fracture	Pepperell et al. (1977) Case 3
49	driver front impact	restrained	37	minor, placental abruption	stillborn	Pepperell et al. (1977) Case 4
50	driver front impact	restrained	27	minor, placental abruption	stillborn	Pepperell et al. (1977) Case 5
51	driver side impact	restrained	26	minor, placental abruption	skull fracture	Pepperell et al. (1977) Case 6
52	driver side impact	restrained	28	none, placental abruption	stillborn	Pepperell et al. (1977) Case 7
53	driver side impact	restrained	29	minor, placental abruption	stillborn	Pepperell et al. (1977) Case 8
54	driver front impact	restrained	22	minor, uterine rupture	stillborn	Pepperell et al. (1977) Case 9
55	passenger front impact	none	36	minor, placental abruption	stillborn	Pepperell et al. (1977) Case 10
56	passenger front impact	none	26	moderate, placental abruption	stillborn	Pepperell et al. (1977) Case 11
57	passenger side impact	none	38	moderate	stillborn	Pepperell et al. (1977) Case 12
58	passenger side impact	none	37	minor, placental abruption, uterine rupture	stillborn	Pepperell et al. (1977) Case 13
59	passenger side impact	restrained	30	minor, uterine rupture	stillborn	Pepperell et al. (1977) Case 14
60	passenger front impact	restrained	32	none, placental abruption	stillborn	Pepperell et al. (1977) Case 15
61	passenger side impact	restrained	36	moderate, placental abruption	stillborn	Pepperell et al. (1977) Case 16
62	passenger side impact	restrained	30	minor, placental abruption	stillborn	Pepperell et al. (1977) Case 17
63	passenger front impact	restrained	34	minor, placental abruption	stillborn	Pepperell et al. (1977) Case 18
64	passenger rollover	restrained	28	minor, placental abruption	rib fracture, liver rupture	Pepperell et al. (1977) Case 19
65	passenger front impact	restrained	34	minor, placental abruption	stillborn	Pepperell et al. (1977) Case 20
66	passenger front impact	restrained	37	minor, placental abruption	stillborn	Pepperell et al. (1977) Case 21
67	passenger front impact	none	38	<i>major</i>	stillborn	Pepperell et al. (1977) Case 23

No.	Occupant Position Impact Direction Impact Severity	Restraint	Gest Age (wk)	Maternal Injuries (italics indicate maternal fatality)	Fetal Outcome (italics indicate fetal survival)	Case Source
68	driver front impact	none	34	<i>major, placental abruption</i>	skull fracture	Pepperell et al. (1977) Case 24
69	passenger side impact	none	34	<i>major, pelvic fx, placental abruption</i>	stillborn	Pepperell et al. (1977) Case 25
70	passenger front impact	none	26	<i>major</i>	stillborn	Pepperell et al. (1977) Case 26
71	front passenger side impact	none	31	minor, pelvic fx, partial placental abruption, uterine laceration	skull fracture, scalp laceration	Poulson and Gabert (1973)
72	driver front impact minor crash	none	36	none, partial placental abruption	<i>emergency C/S, premature</i>	Punnonan (1974)
73	front passenger front impact	lap belt	28	minor, partial placental abruption	brain hemorrhages	Raney (1970)
74	front passenger front impact	none	36	minor, placental laceration	stillborn	Ravangard and Porter (1980)
75	driver front impact minor crash	none	39	none, partial placental abruption	lacerated spleen	Rothenberger et al. (1981)
76	front passenger front impact	lap belt	22	minor, placental abruption, uterine rupture	decapitation	Rowe et al. (1996)
77	front passenger front impact severe crash	lap belt	24	minor, uterine rupture	stillborn	Rubovits (1964)
78	driver front impact severe crash	restrained + airbag	28	minor, partial placental abruption	stillborn	Schultze et al. (1998)
79	front passenger front impact minor crash	none	37	minor, partial placental abruption	<i>delivery within 24 hours</i>	Sherer et al. (1997)
80	driver side impact	none	27	pelvic fx	skull fracture, brain hemorrhages, thoracic hemorrhages	Sherer et al. (1993)
81	driver front impact	none	36	none	splenic rupture	Siddall-allum et al. (1991)
82	driver side impact minor crash	restrained + airbag	39	none	<i>no complications</i>	Sims et al. (1996) Case 1
83	driver front impact moderate crash	restrained + airbag	35	minor	<i>no complications</i>	Sims et al. (1996) Case 2
84	driver minor crash	restrained + airbag	33	minor	<i>contractions stopped without intervention</i>	Sims et al. (1996) Case 3
85	front passenger front crash	none	32	moderate, placental abruption, uterine laceration	stillborn	Smith et al. (1994) Case 1
86	front passenger side impact	none	37	minor, pelvic fx, uterine laceration	stillborn	Smith et al. (1994) Case 2
87	driver front	none	36	none, partial placental abruption	chest hemorrhages	Stafford et al. (1988) Case 2
88	driver front impact	none	21	minor, placental laceration	stillborn	Stafford et al. (1988) Case 3
89	front passenger front impact	none	33	minor, partial placental abruption	brain hemorrhages	Stafford et al. (1988) Case 4

No.	Occupant Position Impact Direction Impact Severity	Restraint	Gest Age (wk)	Maternal Injuries (italics indicate maternal fatality)	Fetal Outcome (italics indicate fetal survival)	Case Source
90	front passenger multiple impact	3-pt belt	34	none, pelvic fx, partial placental abruption	skull fracture, brain contusions and lacerations	Stafford et al. (1988) Case 5
91	driver front impact	lap belt	33	minor, placental damage	skull fracture, brain hemorrhage	Stafford et al. (1988) Case 6
92	driver front impact	none	32	minor, pelvic fx, placental damage	brain hemorrhages	Stafford et al. (1988) Case 7
93	driver front impact	none	27	minor, partial placental abruption	brain hemorrhages	Stafford et al. (1988) Case 8
94	driver front impact severe crash	lap belt	34	moderate, placental laceration	stillborn	Stuart et al. (1980) Case 1
95	driver front impact severe crash	none	28	minor, placental laceration	stillborn	Stuart et al. (1980) Case 2
96	front passenger front impact	3-pt belt	30	minor, uterine rupture	strangled by cord	Svendsen and Morild (1988)
97	front passenger multiple impact	3-pt belt	32	moderate, uterine rupture	stillborn	Van Enk and Van Zwam (1994)
98	driver side impact	none	24	moderate, placental laceration, uterine laceration	stillborn	Weinstein and Pallais (1968)
99	front passenger side impact	lap belt	24	minor	<i>spinal cord damage/paraplegia</i>	Weyerts et al. (1992)
100	driver front impact severe crash	3-pt belt	34	minor, placental abruption	stillborn	Whitehouse (1974)

Appendix B
Consent Form

INFORMED CONSENT FOR EXPERIMENTAL PROCEDURE

**Crash Protection and ATD Abdomen Development for Pregnant Women and the Unborn Fetus:
Investigations of Motor-Vehicle Crashes Involving Pregnant Occupants**

Lawrence W. Schneider, Ph. D., Project Director

Research Scientist and Head, Biosciences Division, UMTRI

Mark D. Pearlman, M. D., Principal Investigator

Department of Obstetrics and Gynecology, University of Michigan Medical Center

Co-Investigators: Kathleen Klinich, Jamie Moore, Joel MacWilliams, Tim Compton, UMTRI

The purpose of this study is to investigate motor vehicle accidents involving pregnant women. The results of this study will be used to determine the effectiveness of current restraint systems and interior vehicle designs in preventing injury to pregnant vehicle occupants and the unborn fetus, as well as to develop improved restraint systems for use by pregnant women in the future.

I agree to answer questions regarding my accident, pregnancy, injuries, my child's health after delivery, and how my driving habits have been affected by pregnancy. I will permit investigators to take photographs and measurements of me while I am seated in the accident vehicle if it is possible and safe to do so. I also agree to allow photos taken of me and my vehicle to be used in scientific publications and presentations as long as they are presented in an anonymous form. I agree to sign releases for any medical records that may be relevant to my pregnancy, injuries, and the delivery and, if applicable, the medical condition of my child. I understand that I may experience some emotional trauma as a result of discussing the circumstances of my accident. I understand that my participation in this study is voluntary, that I will be paid for my participation at a rate of \$10/hr, and that I may withdraw from the study at any time without penalty or loss of compensation to which I may be otherwise entitled.

The University of Michigan Transportation Research Institute is a research organization and, as such, my records and personal information may be reviewed by research staff. My records will be kept confidential to the extent provided by federal, state, and local law. I understand that data and photographs will be used only in scientific publications and presentations and will be in an anonymous and/or code form that will not identify me.

In the unlikely event of physical injury from this investigation, the University will provide first-aid medical treatment. Additional medical treatment will be provided in accordance with the determination by the University of its responsibility to provide such treatment. However, the University does not provide compensation to a person who is injured while participating as a subject in research.

If significant new knowledge is obtained during the course of this research that may relate to my willingness to continue participation, I will be informed of this knowledge. The person listed below may be contacted for more information about any aspect of this study. Any questions or concerns about my rights as a research subject may be directed to the Office of Patient-Staff Relations, L5003 Women's Hospital, Telephone 734-763-5456.

One copy of this document will be kept together with research records on this study. A second copy has been given to me to keep. I have read the information given above. I understand the meaning of this information. I agree to the conditions set forth above and have had an opportunity to discuss my concerns regarding my participation in the proposed study. I hereby consent to participate in the study.

Subject:

Father of subject's child (if available):

_____ name (please print)

_____ name (please print)

_____ signature

_____ signature

date: _____

date: _____

witness signature: _____ date: _____

Investigator(s): Lawrence W. Schneider, Ph. D. 936-1103 (work), 996-3861 (home)

Date of IRBMED Initial Approval: 1-9-97

Date of IRBMED Expiration: 1-8-99

IRBMED # 1996-517

Date of Most Recent Consent Form Approval: 1-8-98

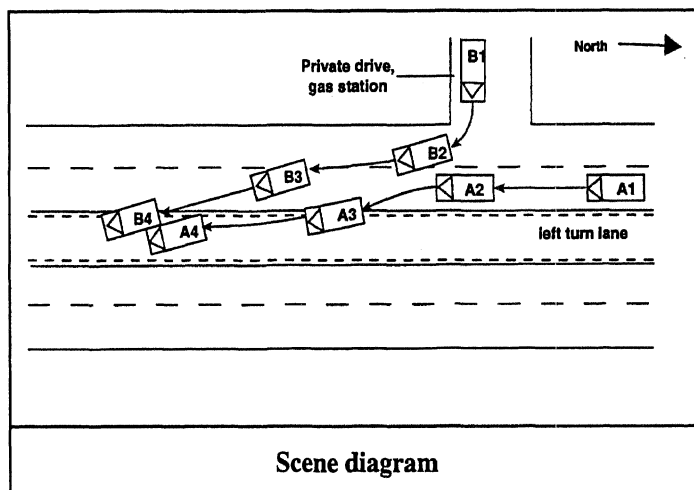
Appendix C

One-Page Summaries of UMTRI Pregnancy Investigations

GMP-001 CASE SUMMARY

PREGNANT OCCUPANT

Position: right front
Gestational Age: 37 weeks
Maternal Age: 21 years
Stature: 155 cm (5' 1")
Mass: 85 kg (187 lb)
Belt Restraint: unbelted
Airbag: not available



IMPACT INFORMATION

Case Vehicle A: 1986 Chevrolet Cavalier
Vehicle B: 1993 Plymouth Sundance
Impact to Case Vehicle: right side (near)
Crash Severity: 9 kph (6 mph) EBS

VEHICLE DAMAGE

CDC: 03-RFEW-2
Maximum Crush: 10 cm to right-front fender
Vehicle Damage: right-front fender to front edge of right passenger door
Relevant Intrusions: none

NEONATAL OUTCOME

The mother reported cessation of fetal movement after the impact, and her membranes broke 1.5 hours later. The infant was born through vaginal delivery within 18 hours of the impact. Birth weight was 3.18 kg (7 lb), and Apgar scores were 8 and 10 at 1 and 2 minutes, respectively. In the first two days, the infant experienced two episodes of apnea and seizure activity and was transferred to the neonatal intensive care unit. A CT scan detected a left peridural/tentorial hemorrhage with a subdural hematoma, rated AIS 4. The infant was discharged after 4 days in stable condition.



Case vehicle damage

NEONATAL INJURIES

MAIS 4, ISS 16

<u>Body Part</u>	<u>Injury</u>	<u>AIS</u>	<u>Suspected Source</u>	<u>Suspected Mechanism</u>
brain, left	peridural/tentorial hemorrhage with subdural hematoma	4	door armrest	direct loading in utero

MATERNAL INJURIES

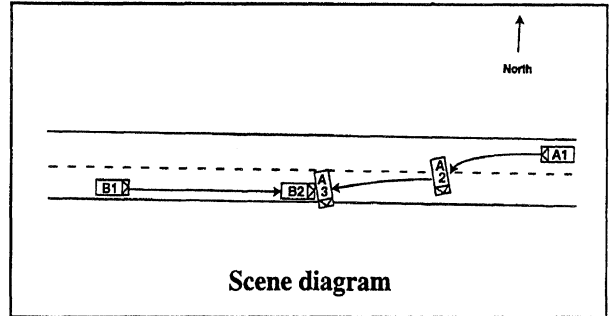
MAIS 1, ISS 2

<u>Body Part</u>	<u>Injury</u>	<u>AIS</u>	<u>Suspected Source</u>	<u>Suspected Mechanism</u>
forehead, right	contusion & abrasion	1	A-pillar	direct contact
knee, left	contusion	1	below IP	direct contact

GMP-002 CASE SUMMARY

PREGNANT OCCUPANT

Position: right front
Gestational Age: 28 weeks
Maternal Age: 18 years
Stature: 160 cm (5' 3")
Mass: 54 kg (119 lb)
Belt Restraint: unbelted
Airbag: not available

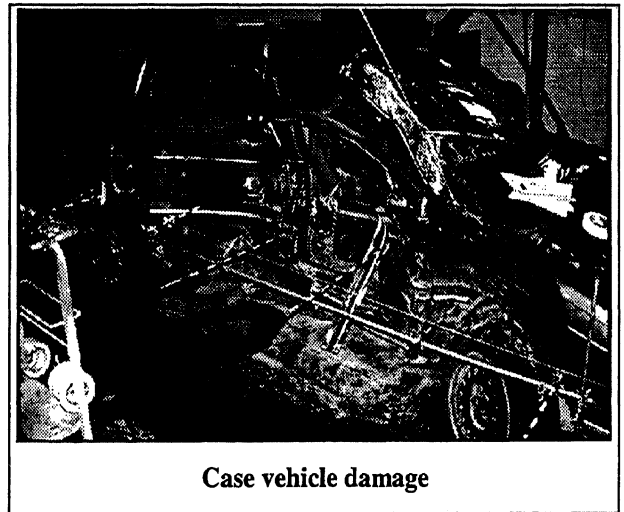


IMPACT INFORMATION

Case Vehicle A: 1989 Ford Tempo
Vehicle B: 1993 Ford Ranger Pickup
Impact to Case Vehicle: right side (near)
Crash Severity: 42 kph (26 mph) delta V

VEHICLE DAMAGE

CDC: 03-RYAW-4
Maximum Crush: 68 cm to right-front door
Vehicle Damage: from behind right front bumper to rear edge of rear door
Relevant Intrusions: right-front door: 44 cm to left
 right B-pillar: 37 cm to left
 right roof siderail: 19 cm to left
 right A-pillar: 4 cm to left



NEONATAL OUTCOME

The fetus died as a result of fatal trauma sustained by the mother.

NEONATAL INJURIES

MAIS 2, ISS 4

<i>Body Part</i>	<i>Injury</i>	<i>AIS</i>	<i>Suspected Source</i>	<i>Suspected Mechanism</i>
arm, left humerus	fracture	2	side-door interior	direct loading in utero

MATERNAL INJURIES

MAIS 4, ISS 26

<i>Body Part</i>	<i>Injury</i>	<i>AIS</i>	<i>Suspected Source</i>	<i>Suspected Mechanism</i>
scalp, left	hemorrhage	1	driver seatback	direct contact
ear, left	contusion	1	driver seatback	direct contact
face, right side	contusion	1	right side flying window glass	direct contact
arm, right upper & lower	abrasions and contusions	1	right side-door interior	direct contact
arm, left	contusions and abrasions	1	driver seatback	direct contact
liver	laceration with severe blood loss	4	right side-door interior	direct loading
buttocks and flank, right	lacerations	1	right side-door interior	direct contact
femur, distal right	fracture	3	right side-door interior	direct contact
leg, right upper & lower	contusions and abrasions	1	seat cushion and right side-door interior	direct contact

Cause of maternal death was respiratory compromise resulting from multiple embolic phenomena complicated by severe hepatic trauma (bone marrow, fat, amniotic fluid, and decidual embolization in lungs.)

GMP-003 CASE SUMMARY

PREGNANT OCCUPANT

Position: right front
Gestational Age: 39 weeks
Maternal Age: 18 years
Stature: 157 cm (5' 2")
Mass: 70 kg (154 lb)
Belt Restraint: unbelted
Airbag: not available

IMPACT INFORMATION

Case Vehicle A: 1986 Ford Tempo
Vehicle B: 1984 Mercedes-Benz 190E
Impact to Case Vehicle: offset frontal (43% vehicle overlap)
Crash Severity: 12 kph (8 mph) EBS

VEHICLE DAMAGE

CDC: 12-FYEW-1
Maximum Crush: 6 cm to left-front bumper corner
Vehicle Damage: from left corner 64 cm across front to center of bumper and hood
Relevant Intrusions: none

NEONATAL OUTCOME

Initial diagnosis of fetus was good. The infant was delivered vaginally 16 days after the crash at 41 weeks gestational age. Birth weight was 3.46 kg (7 lb 10 oz), with Apgar scores of 7 and 9 at 1 and 5 minutes, respectively. The infant was discharged in healthy condition after treatment for a cleft palate unrelated to the crash.

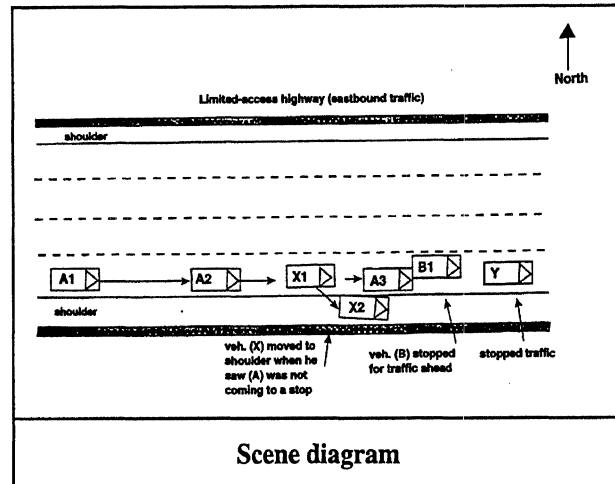
NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 1, ISS 1

<i>Body Part</i>	<i>Injury</i>	<i>AIS</i>	<i>Suspected Source</i>	<i>Suspected Mechanism</i>
forehead, left	contusion	1	rearview mirror	direct contact
back, right	contusion	1	side door	direct contact on rebound



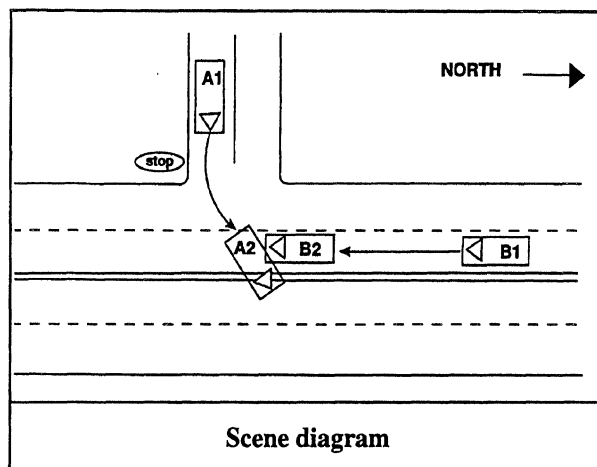
GMP-004 CASE SUMMARY

PREGNANT OCCUPANT

Position: driver
Gestational Age: 19 weeks
Maternal Age: 28 years
Stature: 173 cm (5' 8")
Mass: 59 kg (130 lb)
Belt Restraint: 3-point belt
Airbag: did not deploy

IMPACT INFORMATION

Case Vehicle A: 1994 Ford Taurus
Vehicle B: 1996 Ford Crown Victoria
Impact to Case Vehicle: left side (near)
Crash Severity: 37 kph (23 mph) EBS



VEHICLE DAMAGE

CDC: 10-LPEW-3
Maximum Crush: 50 cm to left-front door
Vehicle Damage: across both left-side door panels
Relevant Intrusions: door panel: 41 cm to right
 A-pillar: 26 cm to right
 door sill: 8 cm to right
 roof side rail: 11 cm to right and 8 cm down
 B-pillar: 27 cm to right
 driver seat: 15 cm to right
 roof: 5 cm down

NEONATAL OUTCOME

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. Birth weight was 2.72 kg (6 lb), with Apgar scores of 9 and 9 at 1 and 5 minutes, respectively.

NEONATAL INJURIES

MAIS 0, ISS 0



Case vehicle damage

MATERNAL INJURIES

MAIS 3, ISS 10

<u>Body Part</u>	<u>Injury</u>	<u>AIS</u>	<u>Suspected Source</u>	<u>Suspected Mechanism</u>
hip, left	contusion	1	side door interior	direct contact
pelvis, sacrum	fracture	2	side door interior	direct loading
pelvis, pubic symphysis	separation	3	side door interior	direct loading
pelvis, bilateral superior pubic rami	fracture	2	side door interior	direct loading
pelvic, bilateral inferior pubic rami	fracture	2	side door interior	direct loading
hip, right	contusion	1	center console/buckle assembly	direct contact
knee, left	contusion	1	side door interior	direct contact

GMP-005 CASE SUMMARY

PREGNANT OCCUPANT

Position: driver
Gestational Age: 23 weeks
Maternal Age: 30 years
Stature: 175 cm (5' 9")
Mass: 102 kg (225 lb)
Belt Restraint: unbelted
Airbag: deployed

IMPACT INFORMATION

Case Vehicle A: 1996 Toyota Corolla
Vehicle B: 1989 Ford Crown Victoria
Impact to Case Vehicle: offset frontal (34% vehicle overlap)
Crash Severity: 12 kph (7 mph) EBS

VEHICLE DAMAGE

CDC: 12-FREW-1
Maximum Crush: 21 cm above right-front bumper corner
Vehicle Damage: right-front corner above bumper
Relevant Intrusions: none

NEONATAL OUTCOME

Initial diagnosis of the fetus was good. The baby was born by cesarean section 18 weeks after the crash at 41 weeks' gestational age. Birth weight was 4.11 kg (9 lb 1 oz), with Apgar scores of 8 and 9 at 1 and 5 minutes, respectively. The neonate was discharged in healthy condition after two days.

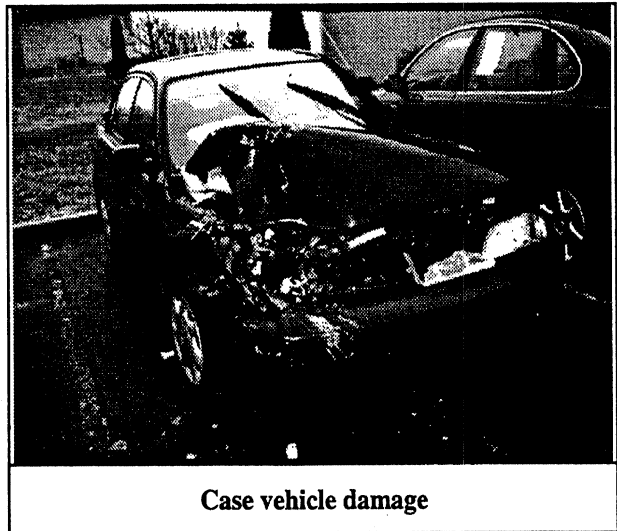
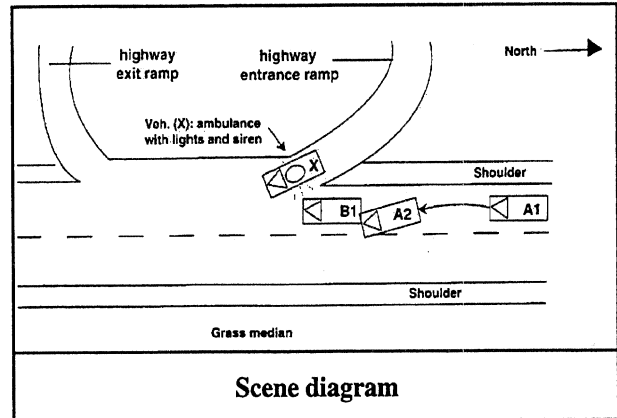
NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 1, ISS 1

<i>Body Part</i>	<i>Injury</i>	<i>AIS</i>	<i>Suspected Source</i>	<i>Suspected Mechanism</i>
mid forehead	abrasion	1	sunvisor	direct contact
chest	contusion	1	airbag	direct contact
knee, left medial	contusion	1	knee bolster	direct contact



GMP-006 CASE SUMMARY

PREGNANT OCCUPANT

Position: driver
Gestational Age: 35 weeks
Maternal Age: 27 years
Stature: 170 cm (5' 7")
Mass: 91 kg (200 lb)
Belt Restraint: 3-point belt
Airbag: deployed

IMPACT INFORMATION

Case Vehicle A: 1993 Dodge Caravan
Vehicle B: 1992 Chevrolet Cavalier
Impact to Case Vehicle: frontal
Estimated Crash Severity: < 24 kph (< 15 mph) EBS

VEHICLE DAMAGE

CDC: 01-FDEW-1
Estimated Max. Crush: minor
Vehicle Damage: across front of vehicle to left side forward of driver's door
Relevant Intrusions: none

NEONATAL OUTCOME

On hospital admission, the mother was experiencing abdominal pain and contractions, and the fetus was in distress. The infant was delivered by emergency cesarean section within 3 hours of the impact, with a birth weight of 2.50 kg (5 lb 8 oz). Apgar scores were 9, 2, and 9 at 1, 5 and 10 minutes, respectively. The cord pH was 7.28. The surgery revealed uterine lacerations approximately 2.5 inches apart, apparently from indirect loading by the lap belt. A partial placental abruption (33%) was also present. The infant was hospitalized for 10 days because of premature respiratory distress syndrome.

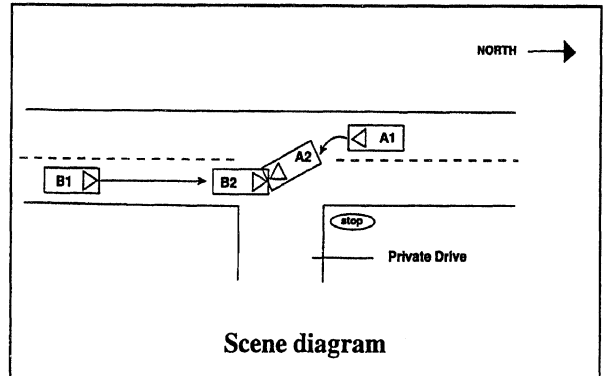
NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 4, ISS 17

<i>Body Part</i>	<i>Injury</i>	<i>AIS</i>	<i>Suspected Source</i>	<i>Suspected Mechanism</i>
forehead	contusion	1	airbag	direct contact
breast, right	contusion	1	shoulder belt	direct contact
abdomen, above umbilicus	contusion	1	lap belt	direct contact
uterus	double laceration	3	lap belt	indirect loading
placenta	partial abruption	4	lap belt	indirect loading



Case vehicle damage (parts removed prior to inspection)

GMP-007 CASE SUMMARY

PREGNANT OCCUPANT

Position: driver
Gestational Age: 35 weeks
Maternal Age: 32 years
Stature: 157 cm (5' 2")
Mass: 59 kg (130 lb)
Belt Restraint: 3-point belt
Airbag: did not deploy

IMPACT INFORMATION

Case Vehicle A: 1996 Jeep Grand Cherokee
Vehicle B: 1991 Thomas School Bus
Impact to Case Vehicle: left side (near)
Crash Severity: 16 kph (10 mph) EBS

VEHICLE DAMAGE

CDC: 10-LYAW-3
Maximum Crush: 13 cm to left-front fender
Vehicle Damage: from left-front bumper corner along left side to rear edge of rear door
Relevant Intrusions: driver-side door panel 7 cm to right

NEONATAL OUTCOME

Initial diagnosis of the fetus immediately after the crash was good. A 3.35 kg (7 lb 6 oz) infant was born through vaginal delivery 5 weeks after the crash at a gestational age of 40 weeks. Apgar scores were 9 and 9 at 1 and 5 minutes, respectively.

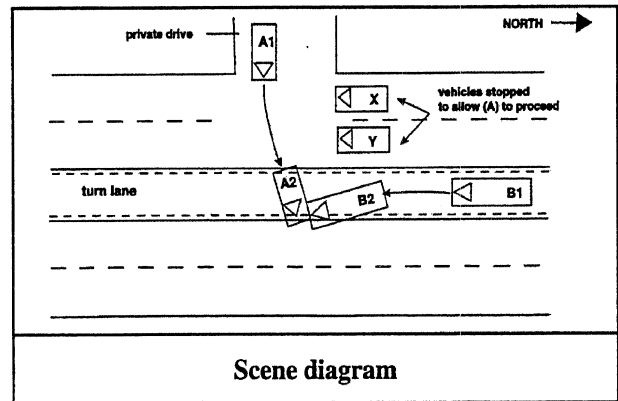
NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 1, ISS 1

<u>Body Part</u>	<u>Injury</u>	<u>AIS</u>	<u>Suspected Source</u>	<u>Suspected Mechanism</u>
head, left side	laceration	1	broken window glass	direct contact
breast, left	contusion	1	side door	direct contact
hip, upper left	contusion	1	side door armrest	direct contact



GMP-008 CASE SUMMARY

PREGNANT OCCUPANT

Position: right front
Gestational Age: 36 weeks
Maternal Age: 26 years
Stature: 157 cm (5' 2")
Mass: 72 kg (158 lb)
Belt Restraint: 3-point belt
Airbag: not available

IMPACT INFORMATION

Case Vehicle A: 1985 Honda Civic
Vehicle B: 1995 Dodge Neon
Impact to Case Vehicle: offset frontal (77% vehicle overlap)
Crash Severity: 25 kph (15 mph) EBS

VEHICLE DAMAGE

CDC: 12-FDEW-2
Maximum Crush: 25 cm to center of front bumper
Vehicle Damage: corner of right-front bumper extending 121 cm across the front
Relevant Intrusions: none

NEONATAL OUTCOME

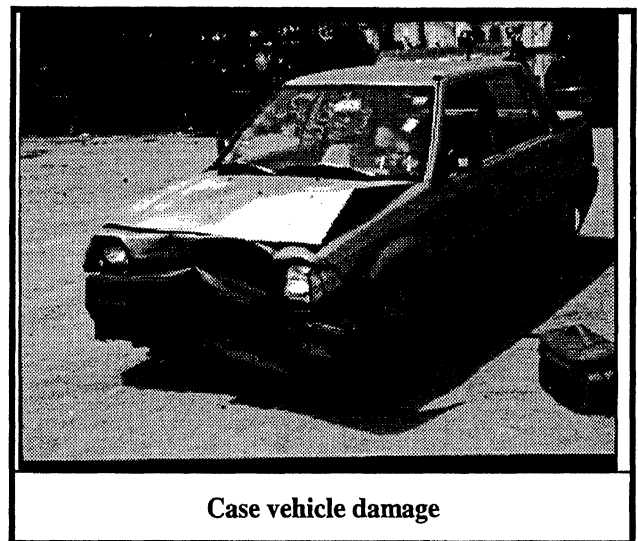
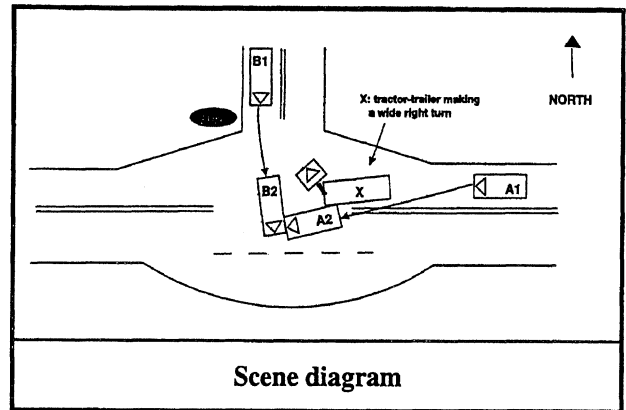
The mother entered the hospital with lower abdominal pain. Contractions began but stopped without intervention within 24 hours. The woman was discharged, and the baby was delivered vaginally 20 days after the crash at 39 weeks gestational age. Birth weight was 3.49 kg (7 lb 11 oz) and Apgar scores were 9 and 9 at 1 and 5 minutes, respectively.

NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 0, ISS 0



GMP-009 CASE SUMMARY

PREGNANT OCCUPANT

Position: right front
Gestational Age: 31 weeks
Maternal Age: 23 years
Stature: 170 cm (5' 7")
Mass: 88 kg (194 lb)
Belt Restraint: 3-point belt
Airbag: deployed

IMPACT INFORMATION

Case Vehicle A: 1996 Chevrolet Lumina
Vehicle B: 1996 Toyota Camry
Impact to Case Vehicle: offset frontal (71% vehicle overlap)
Crash Severity: 16 kph (10 mph) EBS

VEHICLE DAMAGE

CDC: 12-FDEW-1
Maximum Crush: 14 cm to center of front bumper
Vehicle Damage: from left-front bumper corner 120 cm across front of vehicle
Relevant Intrusions: none

NEONATAL OUTCOME

Immediately after the crash, the pregnant occupant experienced contractions that stopped without intervention. Nine weeks after the crash (at 40 weeks gestational age), she vaginally delivered a 3.57 kg (7 lb 14 oz) infant. Apgar scores were 8 and 9 at 1 and 5 minutes, respectively.

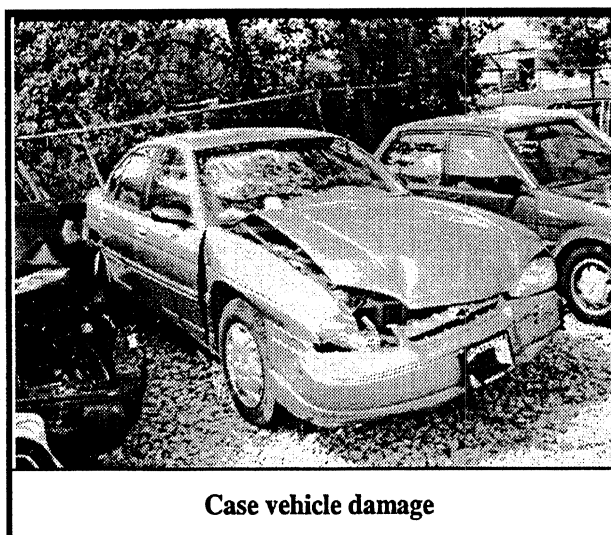
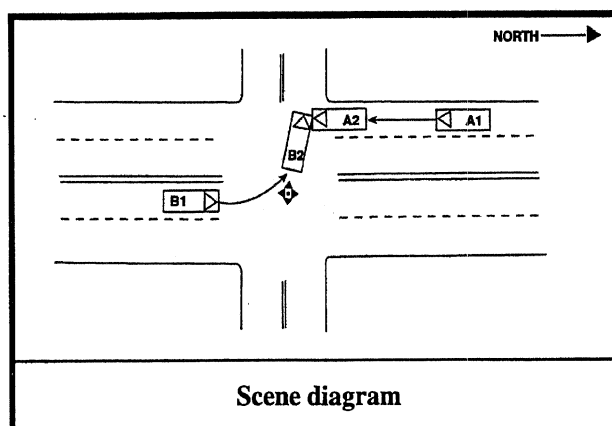
NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 1, ISS 1

<u>Body Part</u>	<u>Injury</u>	<u>AIS</u>	<u>Suspected Source</u>	<u>Suspected Mechanism</u>
lip, lower and upper	contusion	1	airbag	direct contact
lip, lower	laceration	1	airbag	direct contact
chin	abrasion	1	airbag	direct contact
wrist, right anterior	abrasion	1	airbag	direct contact
knee, right	contusion	1	glove compartment	direct contact
knee, left	abrasion	1	glove compartment	direct contact



GMP-010 CASE SUMMARY

PREGNANT OCCUPANT

Position: driver
Gestational Age: 40 weeks
Maternal Age: 30 years
Stature: 175 cm (5' 9")
Mass: 90 kg (198 lb)
Belt Restraint: automatic shoulder/manual lap belt
Airbag: not available

IMPACT INFORMATION

Case Vehicle A: 1992 Saturn SL2
Vehicle B: 1987 Ford Mustang
Impact to Case Vehicle: offset frontal (38% vehicle overlap)
Crash Severity: 71 kph (44 mph) delta V

VEHICLE DAMAGE

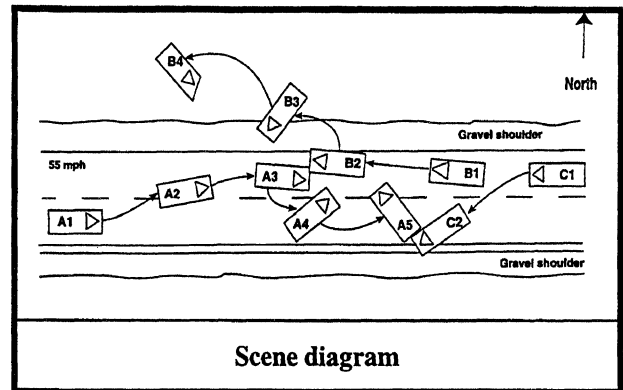
CDC: 12-FYEW-5
Maximum Crush: 125 cm to left front bumper corner
Vehicle Damage: from mid-front around left bumper corner to driver B-pillar
Relevant Intrusions: steering column: 9 cm to rear
IP: 21 cm to rear
toepan: 63 cm to rear
kickpanel: 37 to right
floor: 10 cm up

NEONATAL OUTCOME

The fetus died in utero as a result of placental abruption before arrival at the hospital.

NEONATAL INJURIES

MAIS 0, ISS 0



Case vehicle damage (roof removed by emergency personnel)

GMP-010 CASE SUMMARY (continued)

MATERNAL INJURIES

MAIS 4, ISS 29

<i>Body Part</i>	<i>Injury</i>	<i>AIS</i>	<i>Suspected Source</i>	<i>Suspected Mechanism</i>
forehead, left	contusion	1	steering wheel	direct contact
orbit, left wall	nondisplaced fracture	2	steering wheel	direct contact
gums	laceration	1	steering wheel	direct contact
teeth	fractures/avulsions	1	steering wheel	direct contact
lip	laceration	1	steering wheel	direct contact
chin	contusion	1	steering wheel	direct contact
neck, left	contusion	1	automatic shoulder belt	direct contact
shoulder, left	contusion	1	automatic shoulder belt	direct contact
chest, right	contusion	1	steering wheel or shoulder belt	direct contact
placenta	abruption	4	steering wheel/lap belt	direct loading
abdomen	contusion	1	steering wheel/lap belt	direct contact
femur, left	comminuted fracture	3	mid and lower IP	direct loading
legs & thighs, left and right	contusions	1	IP/steering wheel	direct contact
knee, right	ligament injury	2	lower IP	direct contact
fibula head, right	fracture	2	lower IP	direct contact
tibia, left	fracture	2	mid and lower IP	direct contact
calcaneus, right	fracture	2	toe pan	direct contact
ankle, right	abrasion	1	foot controls	direct contact

GMP-011 CASE SUMMARY

PREGNANT OCCUPANT

Position: driver
Gestational Age: 22 weeks
Maternal Age: 33 years
Stature: 157 cm (5' 2")
Mass: 69 kg (152 lb)
Belt Restraint: 3-point belt
Airbag: deployed

IMPACT INFORMATION

Case Vehicle A: 1992 Plymouth Voyager
Vehicle B: 1995 International tractor-trailer
Impact to Case Vehicle: left side (near)
Crash Severity: 16 kph (10 mph) EBS

VEHICLE DAMAGE

CDC: 10-LYAW-3
Maximum Crush: 23 cm to left-front fender
Vehicle Damage: from left-front bumper corner along left side to rear of driver door
Relevant Intrusions: windshield: 50 cm to rear
 A-pillar: 41 cm to rear, 10 cm to right
 window frame: 38 cm down
 IP: 20 cm to rear
 windshield header: 11 cm down

NEONATAL OUTCOME

Initial diagnosis of the fetus was good. Four months after the crash (at 40 weeks gestational age), the mother vaginally delivered a healthy 3.60 kg (7 lb 15 oz) infant. Apgar scores were 9 and 9 at 1 and 5 minutes, respectively.

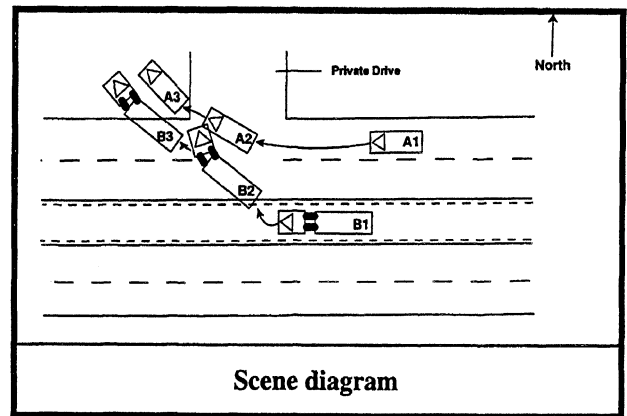
NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 2, ISS 5

<u>Body Part</u>	<u>Injury</u>	<u>AIS</u>	<u>Suspected Source</u>	<u>Suspected Mechanism</u>
brain	concussion/LOC	2	side window frame	direct contact
scalp, left	lacerations	1	side window frame	direct contact
forehead, left	lacerations	1	side window frame	direct contact
chest, center	contusion	1	shoulder belt	direct contact
upper arm, left	lacerations	1	window glass	direct contact
forearm, left	lacerations	1	window glass	direct contact
forearm, left	contusion	1	side-door interior, window glass	direct contact
elbow, left medial	contusion	1	steering wheel/ airbag	direct contact
abdomen, lower right	contusion	1	lap belt	direct contact
knee, right & left	contusions	1	knee bolster	direct contact



GMP-012 CASE SUMMARY

PREGNANT OCCUPANT

Position: right front
Gestational Age: 31 weeks
Maternal Age: 29 years
Stature: 168 cm (5' 6")
Mass: 99 kg (218 lb)
Belt Restraint: 3-point belt
Airbag: did not deploy

IMPACT INFORMATION

Case Vehicle A: 1997 Plymouth Voyager
Vehicle B: 1997 Ford 4-door sedan
Impact to Case Vehicle: right side (near)
Crash Severity: 13 kph (8 mph) EBS

VEHICLE DAMAGE

CDC: 02-RYEW-1
Maximum Crush: 9 cm to right-front fender
Vehicle Damage: along right fender and door panel
Relevant Intrusions: none

NEONATAL OUTCOME

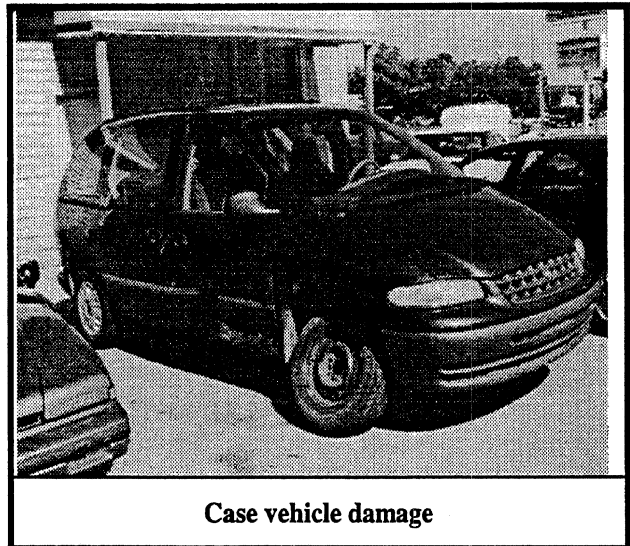
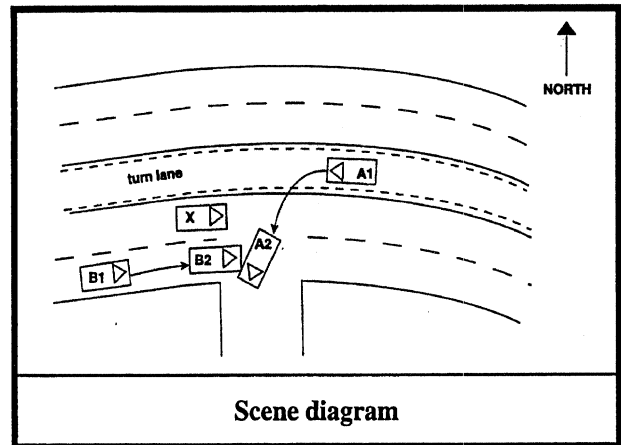
Initial diagnosis of the fetus was good. Eight weeks after the crash, the mother vaginally delivered a healthy infant of 40 weeks gestational age. Birth weight was 3.86 kg (8 lb 8 oz) and Apgar scores were 9 and 9 at 1 and 5 minutes, respectively.

NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 0, ISS 0



GMP-013 CASE SUMMARY

PREGNANT OCCUPANT

Position: left rear (lying down on seat)
Gestational Age: 28 weeks
Maternal Age: 32 years
Stature: 163 cm (5' 4")
Mass: 76 kg (168 lb)
Belt Restraint: unbelted
Airbag: not available

IMPACT INFORMATION

Case Vehicle A: 1988 Ford Aerostar
Vehicle B: none (boulder)
Impact to Case Vehicle: frontal
Crash Severity: 68 kph (42 mph) EBS

VEHICLE DAMAGE

CDC: 12-FDEW-7
Maximum Crush: 73 cm to left-front bumper corner
Vehicle Damage: across entire front
Relevant Intrusions: none

NEONATAL OUTCOME

Initial diagnosis of the fetus was good. Hydrocephaly resulting from intraventricular hemorrhage was diagnosed by ultrasound within a few days of the crash and is suspected to have resulted from the crash. A 2.84 kg (6 lb 4 oz) infant was delivered vaginally at 38 weeks gestational age approximately 10 weeks after the crash and suffered from hydrocephaly.

NEONATAL INJURIES

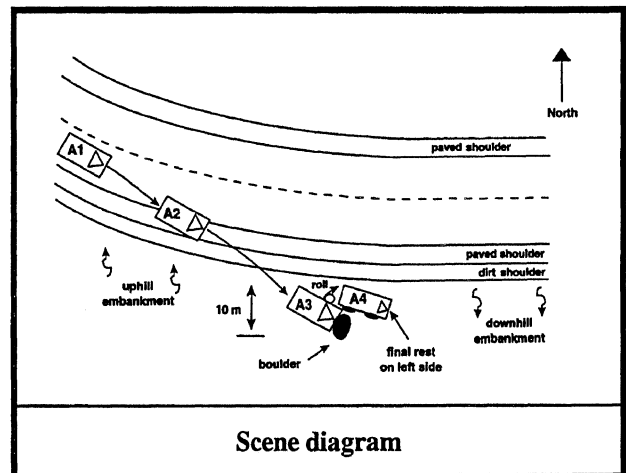
MAIS 4, ISS 16

<u>Body Part</u>	<u>Injury</u>	<u>AIS</u>	<u>Suspected Source</u>	<u>Suspected Mechanism</u>
brain	intraventricular hemorrhage	4	unknown	unknown

MATERNAL INJURIES

MAIS 3, ISS 11

<u>Body Part</u>	<u>Injury</u>	<u>AIS</u>	<u>Suspected Source</u>	<u>Suspected Mechanism</u>
brain	loss of consciousness	2	unknown	unknown
cervical spine	pedicle fx at C5	3	impact force	inertial loading
cervical spine	fx subluxation at C5/C6 with narrowing of spinal canal	2	impact force	inertial loading
shoulder, right	strain	1	unknown	unknown
upper arm, left	laceration	1	unknown	direct contact
leg, right	laceration	1	unknown	direct contact
leg, right	contusion	1	unknown	direct contact



GMP-014 CASE SUMMARY

PREGNANT OCCUPANT

Position: driver
Gestational Age: 26 weeks
Maternal Age: 40 years
Stature: 163 cm (5' 4")
Mass: 70 kg (155 lb)
Belt Restraint: 3-point belt
Airbag: deployed

IMPACT INFORMATION

Case Vehicle A: 1995 Chevrolet Lumina
Vehicle B: 1988 Dodge Dynasty
Impact to Case Vehicle: offset frontal (63% vehicle overlap)
Crash Severity: 11 kph (7 mph) EBS

VEHICLE DAMAGE

CDC: 11-FYEW-1
Maximum Crush: 3 cm to left-front bumper corner
Vehicle Damage: from left bumper corner 96 cm to midfront
Relevant Intrusions: none

NEONATAL OUTCOME

Initial diagnosis of the fetus was good. A healthy infant was delivered vaginally 14 weeks after the crash at a gestational age of 40 weeks. The infant weighed 4.11 kg (9 lb 1 oz), and had Apgar scores of 9 and 9 at 1 and 5 minutes, respectively.

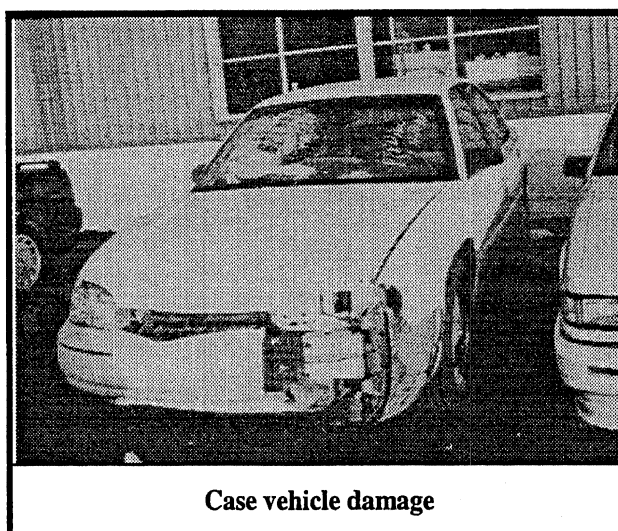
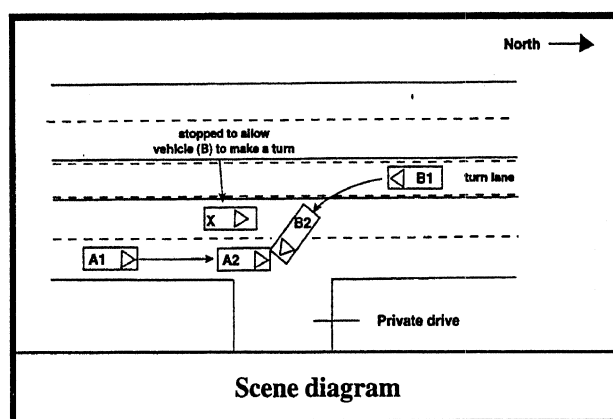
NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 1, ISS 2

<u>Body Part</u>	<u>Injury</u>	<u>AIS</u>	<u>Suspected Source</u>	<u>Suspected Mechanism</u>
shoulder, left	contusion	1	shoulder belt	direct contact
chest, left	contusion	1	shoulder belt	direct contact
foot, right	contusion	1	brake pedal	direct contact
foot, right	sprain	1	brake pedal	direct contact



GMP-015 CASE SUMMARY

PREGNANT OCCUPANT

Position: driver
Gestational Age: 27 weeks
Maternal Age: 17 years
Stature: 180 cm (5' 10")
Mass: 68 kg (150 lb)
Belt Restraint: 3-point belt
Airbag: deployed

IMPACT INFORMATION

Case Vehicle A: 1997 Mercury Sable
Vehicle B: 1996 GMC Sonoma Pickup
Impact to Case Vehicle: offset frontal (31% vehicle overlap)
Crash Severity: 12 kph (8 mph) delta V

VEHICLE DAMAGE

CDC: 01-FLEE-2
Maximum Crush: 1 cm to left-front bumper corner
Vehicle Damage: left-front bumper corner and fender
Relevant Intrusions: none

NEONATAL OUTCOME

Initial diagnosis of the fetus was good. Approximately two months after the crash, at a gestational age of 35 weeks, a 2.18 kg (4 lb 13 oz) infant was delivered. Apgar scores were 9 and 9 at 1 and 5 minutes, respectively. The neonate had dyspnea and respiratory abnormalities resulting from a premature birth that was unrelated to the crash, and was discharged in good health.

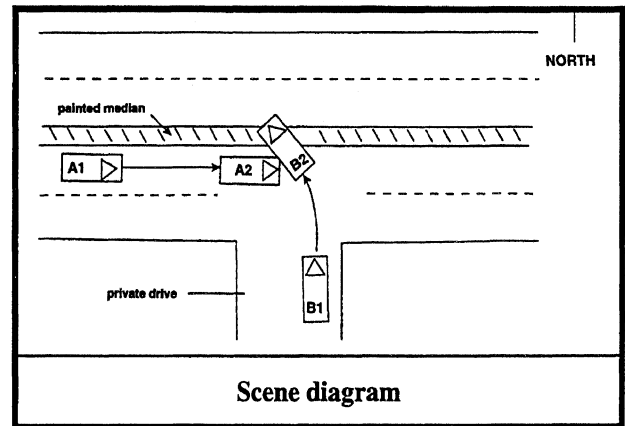
NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 2, ISS 5

<i>Body Part</i>	<i>Injury</i>	<i>AIS</i>	<i>Suspected Source</i>	<i>Suspected Mechanism</i>
cheek, left	contusion	1	airbag	direct contact
forearm, right radius	fracture	2	airbag, airbag cover	direct contact
wrist, right scaphoid	fracture	2	airbag, airbag cover	direct contact



GMP-016 CASE SUMMARY

PREGNANT OCCUPANT

Position: driver
Gestational Age: 23 weeks
Maternal Age: 26 years
Stature: 160 cm (5' 3")
Mass: 89 kg (197 lb)
Belt Restraint: 3-point belt
Airbag: not available

IMPACT INFORMATION

Case Vehicle A: 1994 Suzuki Swift
Vehicle B: 1990 Mercury Sable
Impact to Case Vehicle: frontal
Crash Severity: 23 kph (14 mph) EBS

VEHICLE DAMAGE

CDC: 12-FDEW-1
Maximum Crush: 19 cm to right-front bumper corner
Vehicle Damage: across entire vehicle front
Relevant Intrusions: none

NEONATAL OUTCOME

Initial diagnosis of the fetus was good. A healthy 2.87 kg (6 lb 5 oz) baby was delivered vaginally 4 months after the crash at a gestational age of 39 weeks. Apgar scores were 5 and 9 at 1 and 5 minutes, respectively.

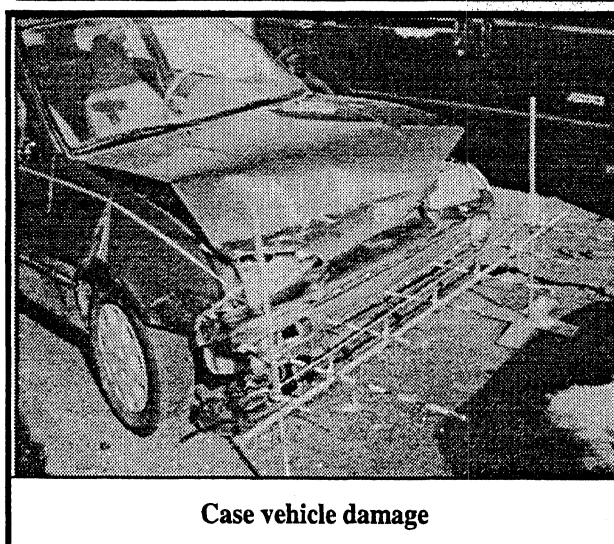
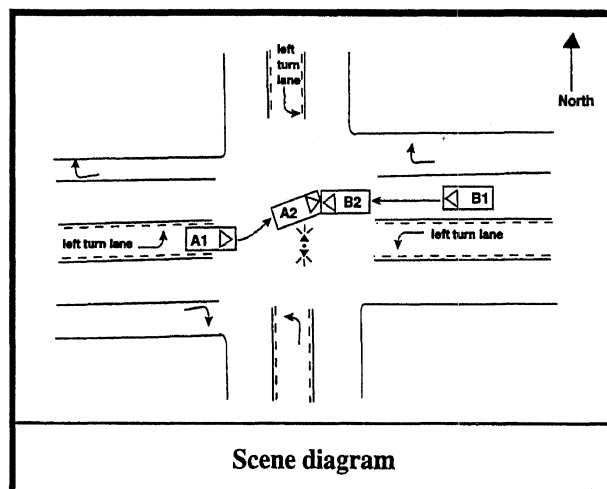
NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 1, ISS 2

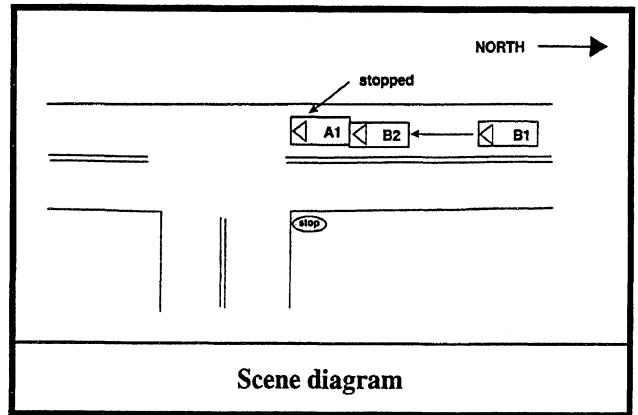
<i>Body Part</i>	<i>Injury</i>	<i>AIS</i>	<i>Suspected Source</i>	<i>Suspected Mechanism</i>
upper arm, right	contusion	1	interior surface	direct contact
breast, left	contusion	1	steering wheel, shoulder belt	direct contact
breast, right	contusion	1	steering wheel	direct contact
ankle, right	sprain	1	brake pedal	direct contact



GMP-017 CASE SUMMARY

PREGNANT OCCUPANT

Position: driver
Gestational Age: 24 weeks
Maternal Age: 30 years
Stature: 163 cm (5' 4")
Mass: 68 kg (150 lb)
Belt Restraint: 3-point belt
Airbag: did not deploy

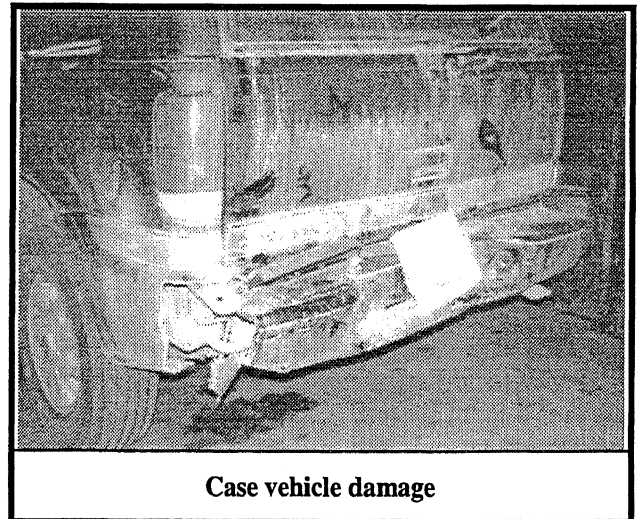


IMPACT INFORMATION

Case Vehicle A: 1998 GMC Jimmy
Vehicle B: 1992 Chevrolet Cavalier
Impact to Case Vehicle: rear
Crash Severity: 15 kph (9 mph) EBS

VEHICLE DAMAGE

CDC: 06-BDLW-1
Maximum Crush: 8 cm to center of rear bumper
Vehicle Damage: across rear bumper of vehicle
Relevant Intrusions: none



NEONATAL OUTCOME

Initial diagnosis of the fetus was good. Approximately 16 weeks after the crash, at a gestational age of 40 weeks, the occupant vaginally delivered a healthy 3.66 kg (8 lb 1 oz) infant. Apgar scores were 7 and 9 at 1 and 5 minutes, respectively.

NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 1, ISS 1

<i>Body Part</i>	<i>Injury</i>	<i>AIS</i>	<i>Suspected Source</i>	<i>Suspected Mechanism</i>
head, left posterior	contusion	1	D-ring assembly/ B-pillar	direct contact

GMP-018 CASE SUMMARY

PREGNANT OCCUPANT

Position: driver
Gestational Age: 21 weeks
Maternal Age: 35 years
Stature: 163 cm (5' 4")
Mass: 58 kg (127 lb)
Belt Restraint: unbelted
Airbag: did not deploy

IMPACT INFORMATION

Case Vehicle A: 1997 Dodge Neon
Vehicle B: none (deer impact)
Impact to Case Vehicle: frontal
Estimated Crash Severity: < 24 kph (15 mph) EBS

VEHICLE DAMAGE

CDC: 12-FDMW-1
Maximum Crush: 13 cm above front bumper
Vehicle Damage: across front of vehicle above bumper
Relevant Intrusions: none

NEONATAL OUTCOME

Initial diagnosis of the fetus was good. A healthy 3.55 kg (7 lb 13 oz) baby was delivered vaginally 19 weeks after the crash at a gestational age of 40 weeks.

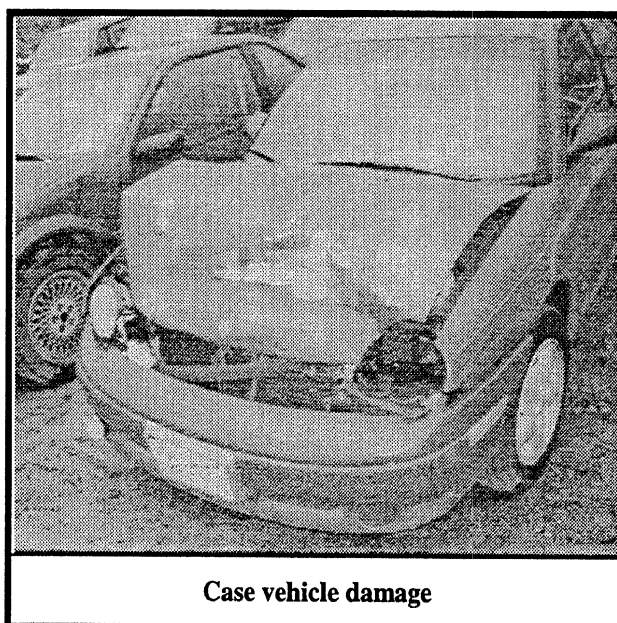
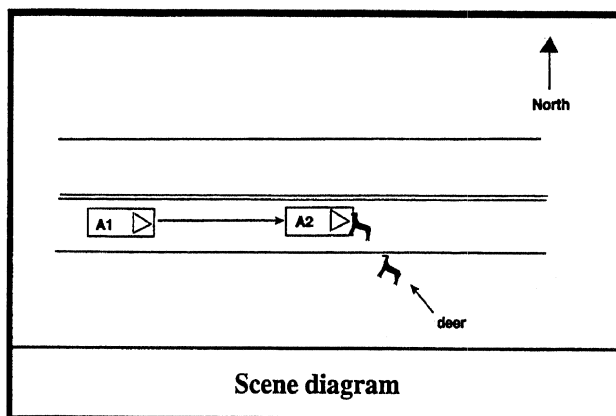
NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 1, ISS 1

<i>Body Part</i>	<i>Injury</i>	<i>AIS</i>	<i>Suspected Source</i>	<i>Suspected Mechanism</i>
neck	cervical strain	1	impact forces	inertial loading



GMP-019 CASE SUMMARY

PREGNANT OCCUPANT

Position: driver
Gestational Age: 26 weeks
Maternal Age: 24 years
Stature: 163 cm (5' 4")
Mass: 78 kg (172 lb)
Belt Restraint: 3-point belt
Airbag: not available

IMPACT INFORMATION

Case Vehicle A: 1988 Pontiac Sunbird
Vehicle B: 1997 Buick LeSabre
Impact to Case Vehicle: offset frontal (36% vehicle overlap)
Crash Severity: 12 kph (7 mph) EBS

VEHICLE DAMAGE

CDC: 12-FREW-1
Maximum Crush: 4 cm to right-front bumper corner
Vehicle Damage: from right-front bumper corner, 45 cm across front
Relevant Intrusions: none

NEONATAL OUTCOME

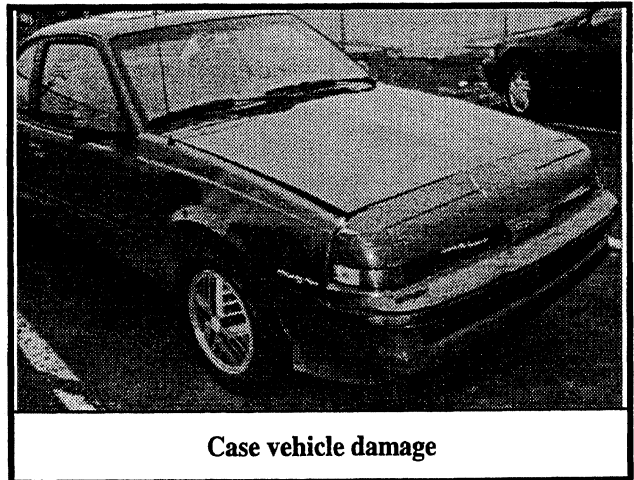
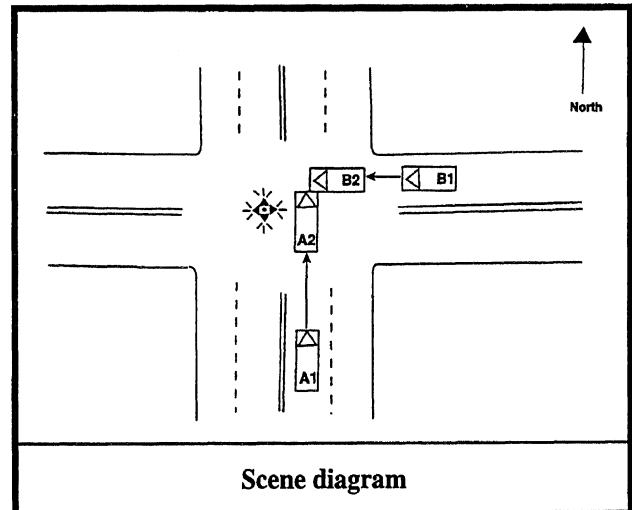
Initial diagnosis of the fetus was good, although the mother experienced abdominal pain. A healthy 3.46 kg (7 lb 10 oz) baby was delivered by cesarean section 14 weeks after the crash at a gestational age of 40 weeks. Apgar scores were 8 and 9 at 1 and 5 minutes, respectively.

NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

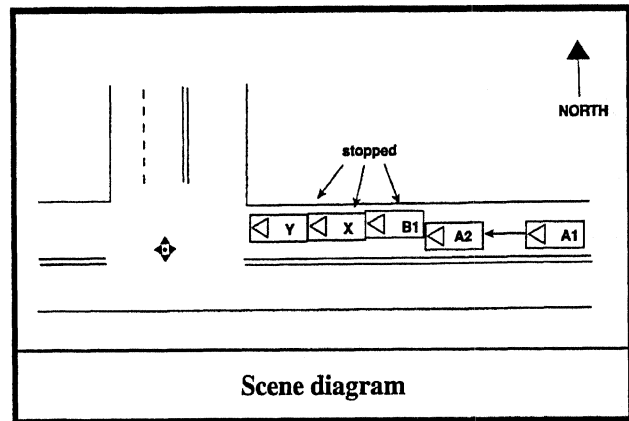
MAIS 0, ISS 0



GMP-020 CASE SUMMARY

PREGNANT OCCUPANT

Position: driver
Gestational Age: 24 weeks
Maternal Age: 31 years
Stature: 160 cm (5' 3")
Mass: 68 kg (150 lb)
Belt Restraint: 3-point belt
Airbag: did not deploy

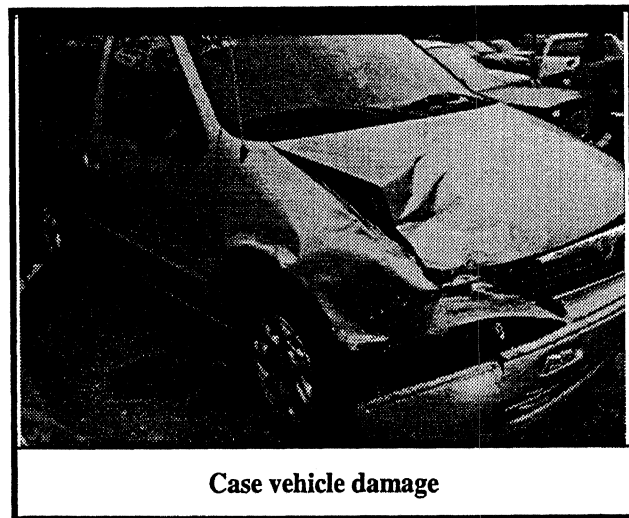


IMPACT INFORMATION

Case Vehicle A: 1997 Mercury Villager
Vehicle B: 1987 Nissan Sentra
Impact to Case Vehicle: offset frontal (35% vehicle overlap)
Crash Severity: 11 kph (7 mph) EBS

VEHICLE DAMAGE

CDC: 12-FREN-1
Maximum Crush: 9 cm to right-front bumper corner
Vehicle Damage: across front right third of vehicle and right-front bumper corner
Relevant Intrusions: none



NEONATAL OUTCOME

Initial diagnosis of the fetus was good. Approximately 16 weeks after the crash, the occupant delivered by cesarean section a healthy 3.21 kg (7 lb 1 oz) infant at a gestational age of 40 weeks. Apgar scores were 7 and 9 at 1 and 5 minutes, respectively.

NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 1, ISS 1

<i>Body Part</i>	<i>Injury</i>	<i>AIS</i>	<i>Suspected Source</i>	<i>Suspected Mechanism</i>
shoulder, left	abrasion	1	shoulder belt	direct contact

GMP-021 CASE SUMMARY

PREGNANT OCCUPANT

Position: driver
Gestational Age: 26 weeks
Maternal Age: 36 years
Stature: 155 cm (5' 1")
Mass: 75 kg (166 lb)
Belt Restraint: 3-point belt
Airbag: not available

IMPACT INFORMATION

Case Vehicle A: 1990 Honda Civic
Vehicle B: Oldsmobile Cutlass
Impact to Case Vehicle: rear
Crash Severity: 14 kph (9 mph) EBS

VEHICLE DAMAGE

CDC: 06-BDLW-1
Maximum Crush: 1 cm to right-rear bumper
Vehicle Damage: across rear bumper of vehicle
Relevant Intrusions: none

NEONATAL OUTCOME

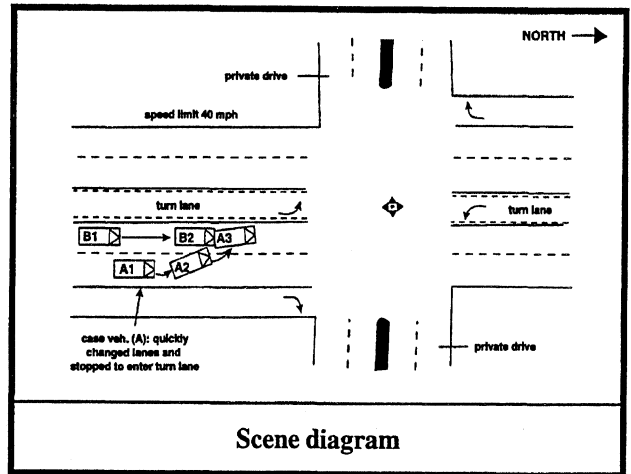
The pregnant occupant did not seek treatment until 3 to 4 hours after the crash. Fetal heart tones could not be found and it was determined that the fetus had died in utero. The autopsy of the 0.94 kg (2 lb 1 oz) fetus did not indicate any signs of trauma to the fetus or placenta.

NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 0, ISS 0



GMP-022 CASE SUMMARY

PREGNANT OCCUPANT

Position: right front (left foot on IP)
Gestational Age: 28 weeks
Maternal Age: 18 years
Stature: 160 cm (5' 3")
Mass: 52 kg (115 lb)
Belt Restraint: automatic shoulder belt only
Airbag: not available

IMPACT INFORMATION

Case Vehicle A: 1990 Ford Tempo
Vehicle B: 1990 Chevrolet Beretta
Impact to Case Vehicle: offset frontal (59% vehicle overlap)
Crash Severity: 23 kph (14 mph) delta V

VEHICLE DAMAGE

CDC: 11-FYEW-2
Maximum Crush: 39 cm to center of front bumper
Vehicle Damage: from left-front bumper corner across two-thirds of vehicle front
Relevant Intrusions: none

NEONATAL OUTCOME

The fetus was delivered by emergency cesarean section at a gestational age of 28 weeks because of maternal death. The infant suffered typical complications resulting from a premature birth, but showed no other problems from trauma.

NEONATAL INJURIES

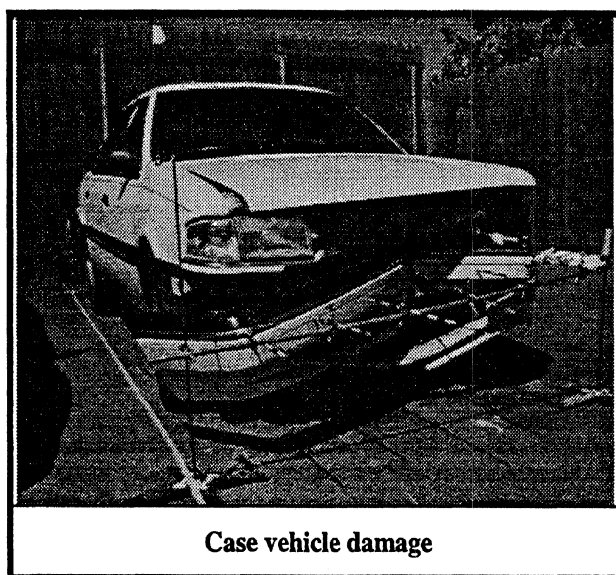
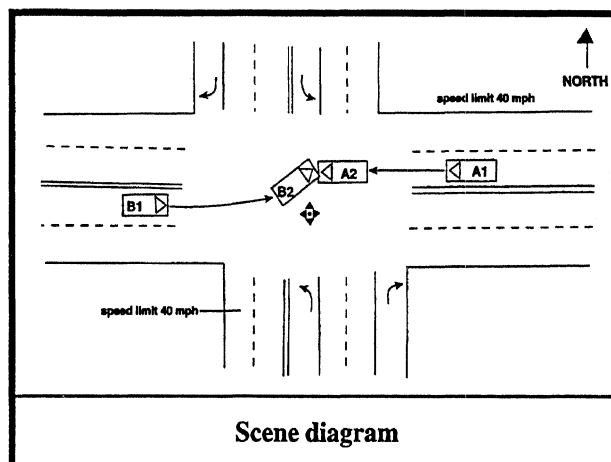
MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 5, ISS 30

<u>Body Part</u>	<u>Injury</u>	<u>AIS</u>	<u>Suspected Source</u>	<u>Suspected Mechanism</u>
left atrial appendage of heart	laceration	5	automatic shoulder belt	direct loading
hilar regions of both lungs	contusions	4	automatic shoulder belt	direct loading
chest, left	abrasion	1	automatic shoulder belt	direct loading
chest, left	contusion	1	automatic shoulder belt	direct loading
spleen	laceration	2	automatic shoulder belt	direct loading
knee, right	abrasion	1	glove box	direct loading
knee, right	contusion	1	glove box	direct loading

The pregnant occupant died prior to arrival at the hospital from blood loss resulting from these injuries.



GMP-023 CASE SUMMARY

PREGNANT OCCUPANT

Position: right front
Gestational Age: 37 weeks
Maternal Age: 24 years
Stature: 163 cm (5' 4")
Mass: 64 kg (141 lb)
Belt Restraint: 3-point belt
Airbag: deployed

IMPACT INFORMATION

Case Vehicle A: 1996 Nissan Maxima
Vehicle B: 1991 Chevrolet Caprice Classic
Impact to Case Vehicle: offset frontal (71% vehicle overlap)
Crash Severity: 24 kph (15 mph) EBS

VEHICLE DAMAGE

CDC: 12-FDEW-2
Maximum Crush: 32 cm to center of front bumper
Vehicle Damage: from left-front bumper corner 110 cm across vehicle front
Relevant Intrusions: none

NEONATAL OUTCOME

Initial diagnosis of the fetus was good. Approximately 2 weeks after the crash, at a gestational age of 39 weeks, the pregnant occupant vaginally delivered a healthy 3.46 kg (7 lb 10 oz) baby. Apgar scores were 9 and 9 at 1 and 5 minutes, respectively. The infant sustained a fractured clavicle during delivery that was unrelated to the crash

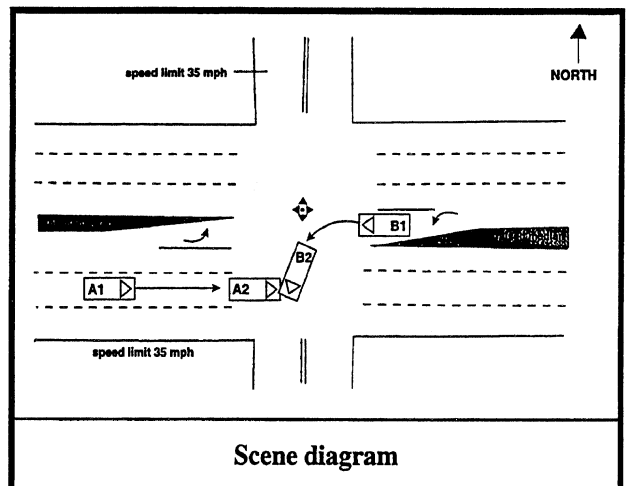
NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 2, ISS 5

<u>Body Part</u>	<u>Injury</u>	<u>AIS</u>	<u>Suspected Source</u>	<u>Suspected Mechanism</u>
chin	abrasion	1	airbag	direct contact
shoulder, right	contusion	1	shoulder belt	direct contact
sternum	fracture	2	shoulder belt	direct contact
chest	contusion	1	shoulder belt	direct contact
abdomen, lower	contusion	1	lap belt	direct contact
thigh, right	abrasion	1	lap belt or airbag	direct contact



GMP-024 CASE SUMMARY

PREGNANT OCCUPANT

Position: right front
Gestational Age: 22 weeks
Maternal Age: 24 years
Stature: 168 cm (5' 6")
Mass: 64 kg (140 lb)
Belt Restraint: unbelted
Airbag: deployed

IMPACT INFORMATION

Case Vehicle A: 1997 Pontiac Sunfire
Vehicle B: 1995 Freightliner tractor-trailer
Impact to Case Vehicle: left side (far)
Estimated Crash Severity: 24 to 48 kph (15 to 30 mph) EBS

VEHICLE DAMAGE

CDC: 12-FLEE-9
Estimated Max. Crush: extensive
Vehicle Damage: down left side of vehicle
Relevant Intrusions: none

NEONATAL OUTCOME

Initial diagnosis of the fetus was good. Approximately 18 weeks after the crash at a gestational age of 40 weeks, the patient vaginally delivered a healthy 3.49 kg (7 lb 10 oz) baby.

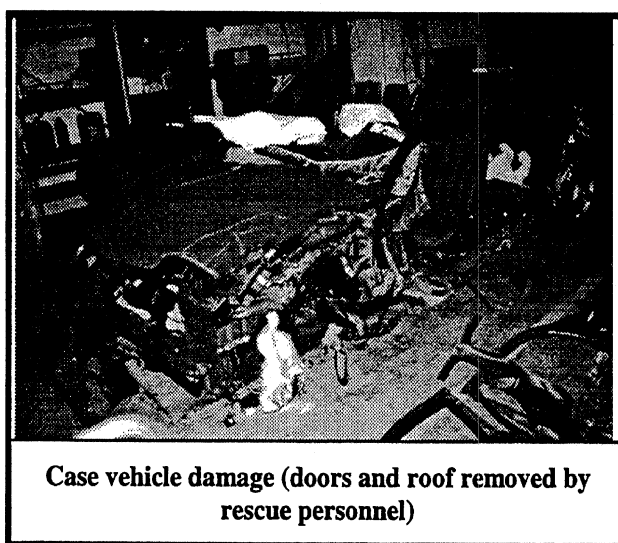
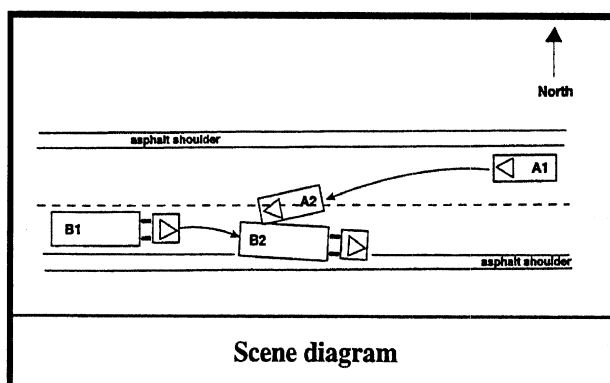
NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 1, ISS 1

<u>Body Part</u>	<u>Injury</u>	<u>AIS</u>	<u>Suspected Source</u>	<u>Suspected Mechanism</u>
knee, left right	contusions	1	glove box	direct contact



GMP-025 CASE SUMMARY

PREGNANT OCCUPANT

Position: driver
Gestational Age: 39 weeks
Maternal Age: 35 years
Stature: 163 cm (5' 4")
Mass: 66 kg (145 lb)
Belt Restraint: 3-point belt
Airbag: deployed

IMPACT INFORMATION

Case Vehicle A: 1998 Dodge Stratus
Vehicle B: 1996 GMC K1500 Pickup
Impact to Case Vehicle: frontal
Crash Severity: 28 kph (17 mph) EBS

VEHICLE DAMAGE

CDC: 12-FDEW-2
Maximum Crush: 40 cm to center front bumper
Vehicle Damage: across front of vehicle
Relevant Intrusions: none

NEONATAL OUTCOME

Initial diagnosis of the fetus was good. Approximately 2 weeks after the crash, at a gestational age of 41 weeks, the pregnant occupant vaginally delivered a healthy 3.20 kg (7 lb 1 oz) baby. Apgar scores were 9 and 9 at 1 and 5 minutes, respectively.

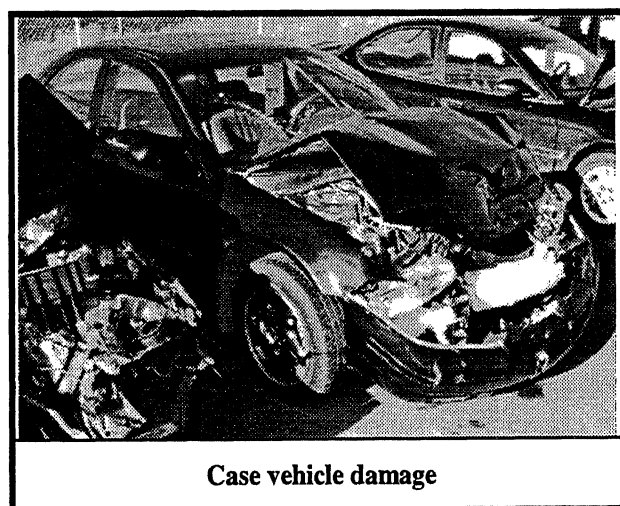
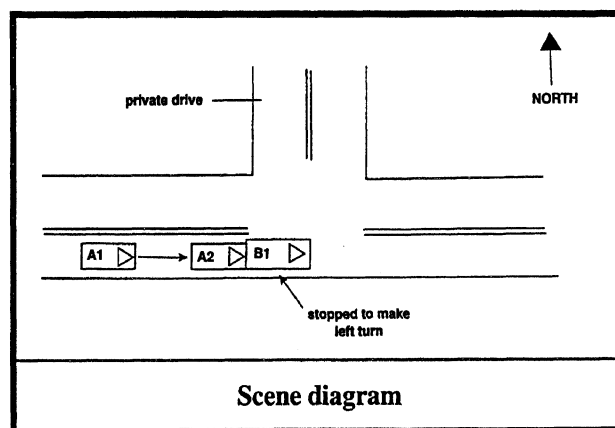
NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 1, ISS 1

<u>Body Part</u>	<u>Injury</u>	<u>AIS</u>	<u>Suspected Source</u>	<u>Suspected Mechanism</u>
hand, left	contusion	1	windshield	direct contact (fling from airbag)
hand, right	contusion	1	steering wheel	direct contact
knee, left	contusion	1	knee bolster	direct contact



GMP-026 CASE SUMMARY

PREGNANT OCCUPANT

Position: right front
Gestational Age: 30 weeks
Maternal Age: 18 years
Stature: 152 cm (5')
Mass: 68 kg (150 lb)
Belt Restraint: 3-point belt
Airbag: deployed

IMPACT INFORMATION

Case Vehicle A: 1998 Chevrolet Cavalier
Vehicle B: 1994 Mitsubishi Gallant
Impact to Case Vehicle: frontal
Crash Severity: 41 kph (25 mph) delta V

VEHICLE DAMAGE

CDC: 12-FDEW-3
Maximum Crush: 57 cm to center front bumper
Vehicle Damage: across front of vehicle
Relevant Intrusions: toepan: 15 cm rearward
 IP: 1 cm rearward

NEONATAL OUTCOME

Initial diagnosis of the fetus was good. Approximately 9 weeks after the crash at a gestational age of 39 weeks, the mother vaginally delivered a 2.52 kg (5 lb 9 oz) baby. The infant sustained a right clavicle fracture as a result of difficult childbirth. 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. (Synostosis is a union of normally separate bones.) These complications are suspected to have resulted from the trauma of the crash.

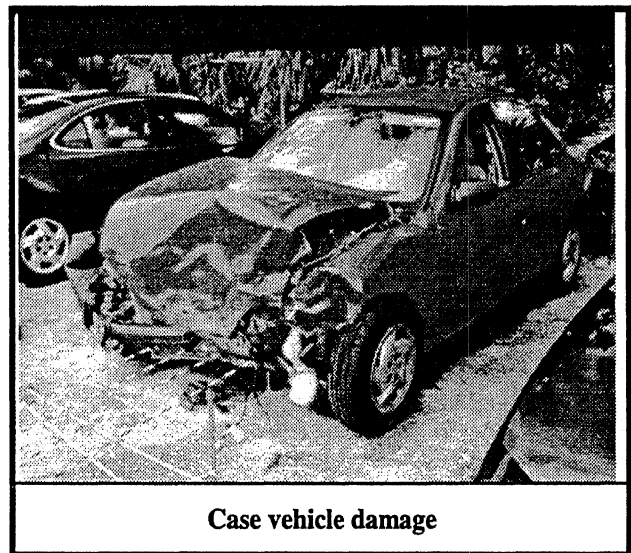
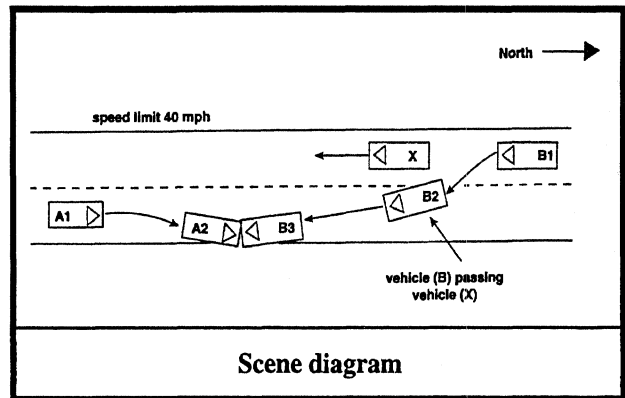
NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 3, ISS 10

<u>Body Part</u>	<u>Injury</u>	<u>AIS</u>	<u>Suspected Source</u>	<u>Suspected Mechanism</u>
clavicle, right	abrasion	1	shoulder belt	direct contact
finger, middle right	abrasion	1	airbag	direct contact
radius, right	comminuted fracture	3	IP	direct contact
breast, left	contusion	1	shoulder belt	direct contact
abdomen, left	contusion	1	lap/shoulder belt	direct contact
abdomen, right	abrasion	1	lap/shoulder belt	direct contact
flank, left	contusion	1	lap belt, belt buckle	direct contact
thigh, right	contusion	1	airbag	direct contact
knee, right	contusion	1	knee bolster	direct contact
leg, right anterior	laceration	1	knee bolster	direct contact
fibula, left and right	fracture	2	floor/toepan	direct contact
tibia, left and right	fracture	2	floor/toepan	direct contact



GMP-027 CASE SUMMARY

PREGNANT OCCUPANT

Position: driver
Gestational Age: 38 weeks
Maternal Age: 33 years
Stature: 160 cm (5' 3")
Mass: 86 kg (190 lb)
Belt Restraint: 3-point belt
Airbag: deployed

IMPACT INFORMATION

Case Vehicle A: 1995 Dodge Neon
Vehicle B: 1991 Ford Escort
Impact to Case Vehicle: offset frontal (75% vehicle overlap)
Crash Severity: 13 kph (8 mph) EBS

VEHICLE DAMAGE

CDC: 12-FDEW-1
Maximum Crush: 7 cm to right front bumper corner
Vehicle Damage: across vehicle front
Relevant Intrusions: none

NEONATAL OUTCOME

Initial diagnosis of the fetus was good. A healthy baby of 4.17 kg (9 lb 3 oz) was delivered by planned cesarean section 3 weeks after the crash. Apgar scores were 9 and 9 at 1 and 5 minutes, respectively.

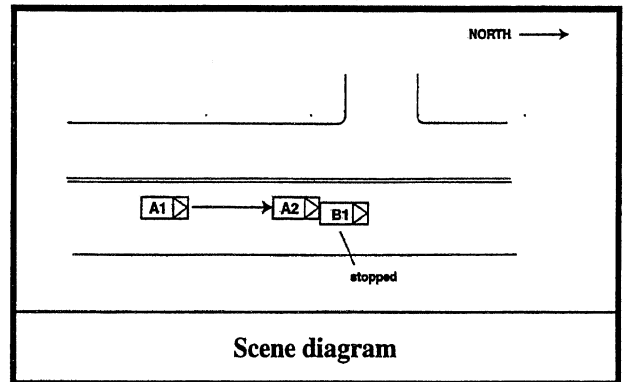
NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 1, ISS 1

<i>Body Part</i>	<i>Injury</i>	<i>AIS</i>	<i>Suspected Source</i>	<i>Suspected Mechanism</i>
hand, left	abrasion	1	airbag	direct contact
hand, right	lacerations	1	broken right side window glass	direct contact
abdomen	contusion	1	airbag	direct contact



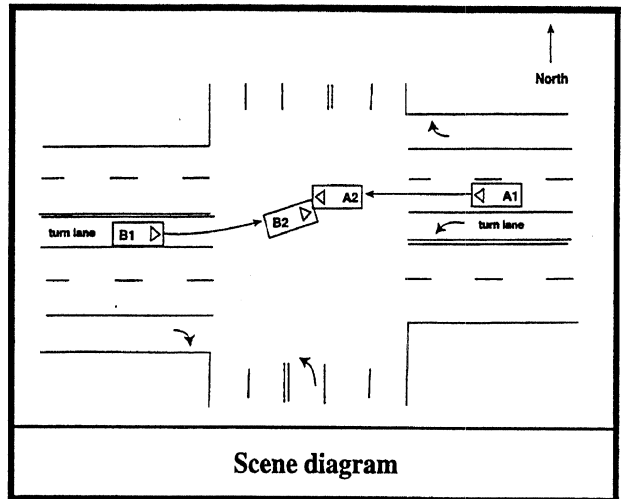
GMP-202 CASE SUMMARY**

PREGNANT OCCUPANT

Position: driver
Gestational Age: 38 weeks
Maternal Age: 25 years
Stature: 175 cm (5' 9")
Mass: 79 kg (175 lb)
Belt Restraint: unbelted
Airbag: deployed

IMPACT INFORMATION

Case Vehicle A: 1996 Ford Contour
Vehicle B: 1995 Chevrolet Cavalier
Impact to Case Vehicle: offset frontal (34% vehicle overlap)
Crash Severity: 12 kph (8 mph) delta V



VEHICLE DAMAGE

CDC: 12-FLEW-1
Maximum Crush: 12 cm to left-front bumper corner
Vehicle Damage: left-front corner
Relevant Intrusions: none

NEONATAL OUTCOME

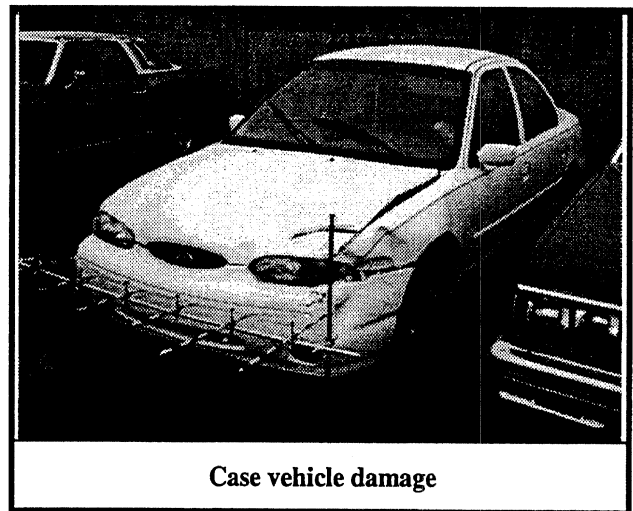
The pregnant driver started having contractions immediately after the crash that were stopped by medical intervention. A healthy 4.09 kg (9 lb) baby was delivered vaginally 2 weeks after the crash.

NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 1, ISS 1



<u>Body Part</u>	<u>Injury</u>	<u>AIS</u>	<u>Suspected Source</u>	<u>Suspected Mechanism</u>
cheek, right	abrasion	1	airbag	direct contact
neck, right	abrasion	1	airbag	direct contact
chest, central	contusion	1	airbag	direct contact
forearm, left	contusion	1	airbag cover	direct contact
knee, left	contusion	1	knee bolster	direct contact
knee, right	contusion	1	steering column	direct contact

**This case does not meet the criteria for a complete pregnancy crash investigation because the baby's medical records are not available to confirm outcome.

GMP-203 CASE SUMMARY**

PREGNANT OCCUPANT

Position: right front
Gestational Age: 40 weeks
Maternal Age: 25 years
Stature: 168 cm (5' 6")
Mass: 70 kg (155 lb)
Belt Restraint: 3-point belt
Airbag: not available

IMPACT INFORMATION

Case Vehicle A: 1993 Ford Taurus
Vehicle B: 1991 Ford Ranger
Impact to Case Vehicle: offset frontal (54% vehicle overlap)
Crash Severity: 43 kph (27 mph) EBS

VEHICLE DAMAGE

CDC: 11-FYEW-3
Maximum Crush: 74 cm to center bumper
Vehicle Damage: from left-front corner, 81 cm across front
Relevant Intrusions: toepan: 8 cm to rear
 glove box: 6 cm to rear

NEONATAL OUTCOME

A healthy baby was delivered the same day as the crash.

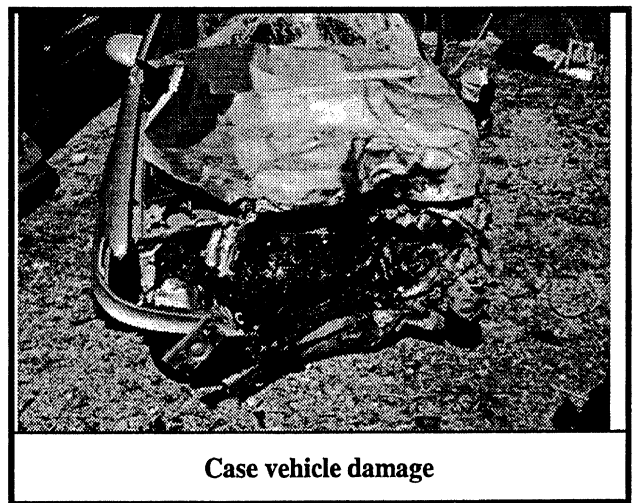
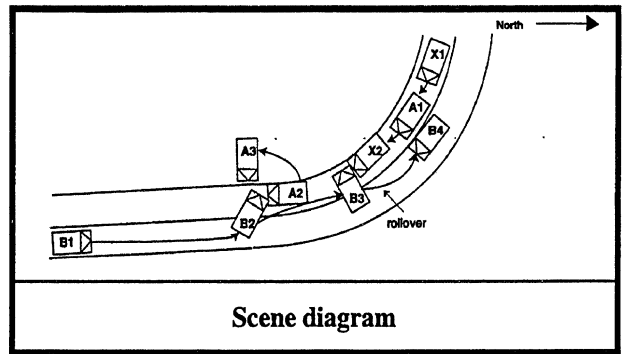
NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 2, ISS 6

<u>Body Part</u>	<u>Injury</u>	<u>AIS</u>	<u>Suspected Source</u>	<u>Suspected Mechanism</u>
forehead, left	abrasion	1	roof	direct contact
cervical spine	strain	1	roof or shoulder belt	indirect contact or inertial loading
chest	abrasion	1	shoulder belt	direct contact
abdomen	abrasion	1	shoulder belt	direct contact
wrist, left	contusion	1	windshield/ IP	direct contact
hand, right	contusion	1	windshield/ IP	direct contact
knee, left	abrasion	1	glove box	direct contact
knee, left	sprain	2	glove box	direct contact
knee, right	abrasion	1	glove box	direct contact



**This case does not meet the criteria for a complete pregnancy crash investigation because the baby's medical records are not available to confirm outcome.

GMP-204 CASE SUMMARY**

PREGNANT OCCUPANT

Position: right front
Gestational Age: 36 weeks
Maternal Age: 22 years
Stature: 165 cm (5' 5")
Mass: 86 kg (190 lb)
Belt Restraint: 3-point belt
Airbag: deployed

IMPACT INFORMATION

Case Vehicle A: 1994 Mercury Cougar
Vehicle B: 1983 Mercury Grand Marquis
Impact to Case Vehicle: offset frontal (62% vehicle overlap)
Crash Severity: 19 kph (12 mph) EBS

VEHICLE DAMAGE

CDC: 11-FZEW-2
Maximum Crush: 39 cm to right-front bumper corner
Vehicle Damage: from right-front bumper corner across front
Relevant Intrusions: none

NEONATAL OUTCOME

Contractions began immediately after the crash and were stopped by medical intervention. A healthy baby was delivered 1 month after the crash.

NEONATAL INJURIES

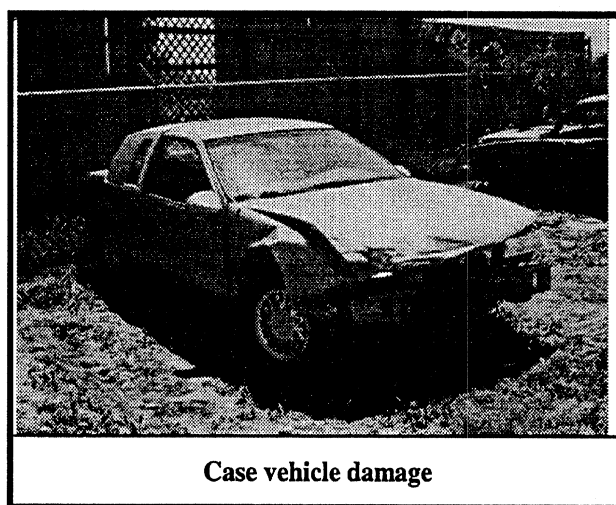
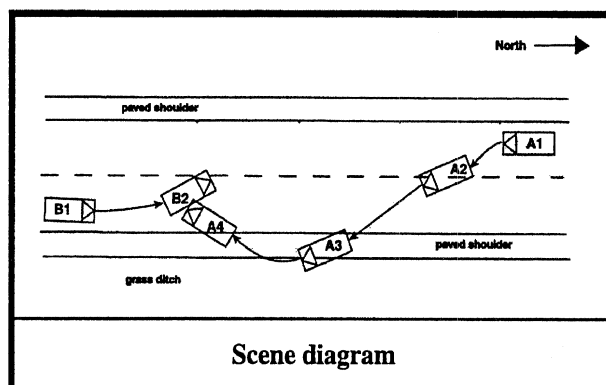
MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 1, ISS 1

<u>Body Part</u>	<u>Injury</u>	<u>AIS</u>	<u>Suspected Source</u>	<u>Suspected Mechanism</u>
cheek, right	abrasion	1	airbag	direct contact
lips	contusion	1	airbag	direct contact
nose	laceration	1	airbag	direct contact
knee, right	contusion	1	mid IP	direct contact
knee, right	abrasion	1	mid IP	direct contact
leg, lower right	laceration	1	mid IP	direct contact

**This case does not meet the criteria for a complete pregnancy crash investigation because the baby's medical records are not available to confirm outcome.



GMP-205 CASE SUMMARY**

PREGNANT OCCUPANT

Position: driver
Gestational Age: 23 weeks
Maternal Age: 26 years
Stature: 173 cm (5' 8")
Mass: 68 kg (150 lb)
Belt Restraint: unbelted
Airbag: not available

IMPACT INFORMATION

Case Vehicle A: 1989 Pontiac Grand Prix
Vehicle B: 1988 Buick LeSabre
Impact to Case Vehicle: right side (far)
Estimated Crash Severity: > 48 kph (30 mph) EBS

VEHICLE DAMAGE

CDC: unknown
Estimated Max. Crush: extensive
Vehicle Damage: right-side damage
Relevant Intrusions: extensive

NEONATAL OUTCOME

Twin fetuses died as a result of maternal death.

NEONATAL INJURIES

MAIS 0, ISS 0

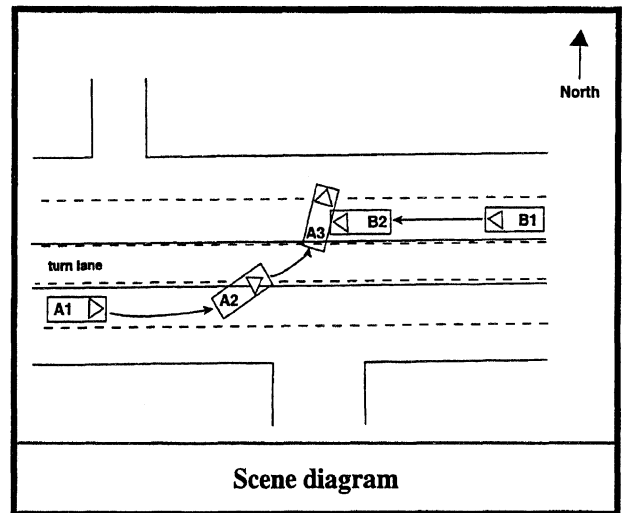
MATERNAL INJURIES

MAIS 5, ISS 30

<i>Body Part</i>	<i>Injury</i>	<i>AIS</i>	<i>Suspected Source</i>	<i>Suspected Mechanism</i>
brain, pons	hemorrhages	5	right-side A-pillar	direct loading
brain	subgaleal hemorrhage	4	right-side A-pillar	direct loading
skull, lambdoidal suture	distatic fracture	2	right-side A-pillar	direct contact
skull, cranial fossae	hinge fracture	4	right-side A-pillar	direct contact
head, right forehead	abrasion	1	right-side A-pillar	direct contact
groin, right	contusion	1	unknown	direct contact
pelvis, left pubic ramus	fracture	2	unknown	direct loading
thigh, right anterior	abrasion	1	unknown	direct contact
knee, left	contusion	1	unknown	direct contact

The pregnant occupant died as a result of severe head injuries.

**This case does not meet the criteria for a complete pregnancy crash investigation because the vehicle was not inspected.

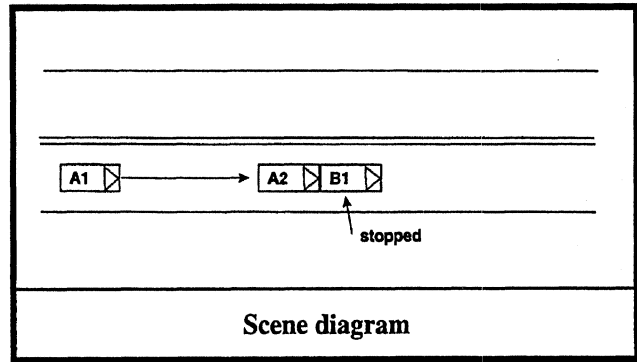


Vehicle damage not available

GMP-206 CASE SUMMARY**

PREGNANT OCCUPANT

Position: driver
Gestational Age: 28 weeks
Maternal Age: unknown
Stature: unknown
Mass: unknown
Belt Restraint: 3-point belt
Airbag: not available

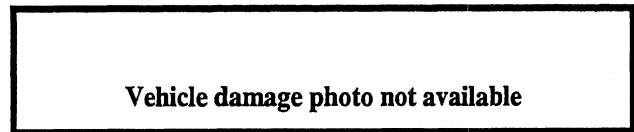


IMPACT INFORMATION

Case Vehicle A: unknown
Vehicle B: unknown
Impact to Case Vehicle: frontal
Estimated Crash Severity: > 48 kph (30 mph) EBS

VEHICLE DAMAGE

CDC: unknown
Maximum Crush: unknown
Vehicle Damage: unknown
Relevant Intrusions: unknown



NEONATAL OUTCOME

The pregnant occupant was examined after the crash and sent home. The next day, she started bleeding vaginally and delivered a stillborn infant.

NEONATAL INJURIES

MAIS 0, ISS 0

The fetus died in utero of unspecified causes.

MATERNAL INJURIES

MAIS 1, ISS 1

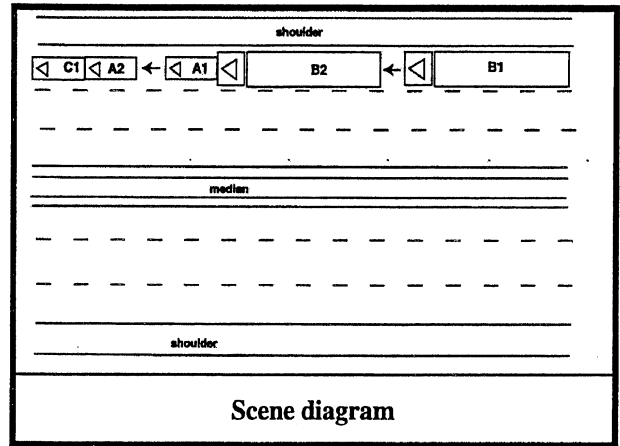
<u>Body Part</u>	<u>Injury</u>	<u>AIS</u>	<u>Suspected Source</u>	<u>Suspected Mechanism</u>
head	contusion	1	unknown	direct contact
abdomen	contusion	1	lap belt	direct contact

**This case does not meet the criteria for a complete pregnancy crash investigation because all of the information came from a single interview with the subject. The vehicle was not inspected and medical records are not available.

GMP-207A CASE SUMMARY**

PREGNANT OCCUPANT

Position: right front
Gestational Age: 34 weeks
Maternal Age: 22 years
Stature: 157 cm (5' 2")
Mass: 86 kg (190 lb)
Belt Restraint: unbelted
Airbag: not available

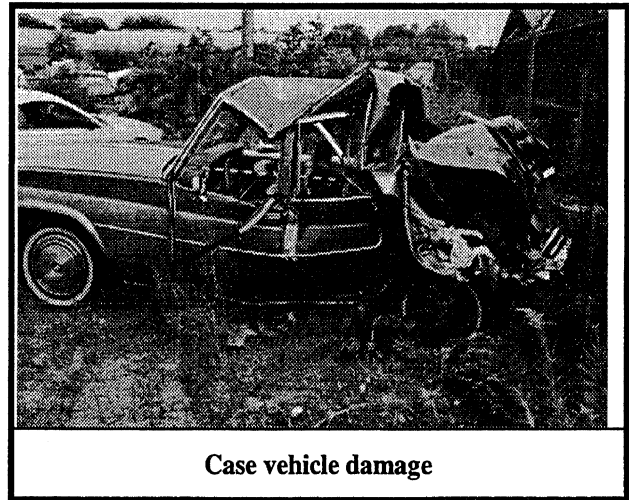


IMPACT INFORMATION

Case Vehicle A: 1985 Buick LeSabre
Vehicle B: 1987 Mack Tractor Trailer
Impact to Case Vehicle: rear, then frontal
Crash Severity: 77 kph (48 mph) EBS

VEHICLE DAMAGE

CDC: 06-BDAW-7, 12-FZLW-1
Maximum Crush: 146 cm to left-rear bumper corner
Vehicle Damage: across entire rear of vehicle
Relevant Intrusions: front seatback: 21 cm to front
 right B-pillar: 8 cm to left



NEONATAL OUTCOME

The pregnant occupant sustained a placental abruption and delivered a premature infant the day of the crash by emergency cesarean delivery.

NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 3, ISS 10

<u>Body Part</u>	<u>Injury</u>	<u>AIS</u>	<u>Suspected Source</u>	<u>Suspected Mechanism</u>
forehead	contusion	1	mid IP	direct contact
face, left	abrasions	1	flying glass	direct contact
placenta	abruption	3	intruding seatback	inertial loading
			IP	direct loading
knee, right	contusion	1	lower IP	direct contact

**This case does not meet the criteria for a complete pregnancy crash investigation because the baby's medical records are not available to confirm outcome.

GMP-207B CASE SUMMARY**

PREGNANT OCCUPANT

Position: right rear
Gestational Age: 32 weeks
Maternal Age: 20 years
Stature: 150 cm (4' 11")
Mass: 94 kg (207 lb)
Belt Restraint: unbelted
Airbag: not available

IMPACT INFORMATION

Case Vehicle A: 1985 Buick LeSabre
Vehicle B: 1987 Mack Tractor Trailer
Impact to Case Vehicle: rear, then front
Crash Severity: 77 kph (48 mph) EBS

VEHICLE DAMAGE

CDC: 06-BDAW-7, 12-FZLW-1
Maximum Crush: 146 cm to left-rear bumper corner
Vehicle Damage: across entire rear of vehicle
Relevant Intrusions: rear seatback: 13 cm to front
right C-pillar: 7 cm to front

NEONATAL OUTCOME

The pregnant occupant sustained a placental abruption and delivered a premature infant the day of the crash by emergency cesarean section. The fetus suffered a possible head injury.

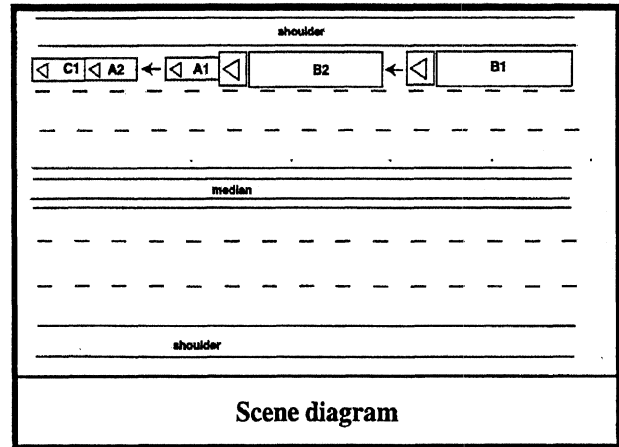
NEONATAL INJURIES

MAIS unknown, ISS unknown

MATERNAL INJURIES

MAIS 3, ISS 10

<u>Body Part</u>	<u>Injury</u>	<u>AIS</u>	<u>Suspected Source</u>	<u>Suspected Mechanism</u>
chest, left	contusion	1	front seatback	direct contact
placenta	abruption	3	intruding seatback	inertial loading
			front seatback	direct contact
lower back	contusion	1	intruding seatback	direct contact
knee, right	contusion	1	front seatback	direct contact
knee, left	contusion	1	front seatback	direct contact



**This case does not meet the criteria for a complete pregnancy crash investigation because the baby's medical records are not available to confirm outcome.

GMP-208 CASE SUMMARY**

PREGNANT OCCUPANT

Position: driver
Gestational Age: 24 weeks
Maternal Age: unknown
Stature: 173 cm (5' 8")
Mass: 68 kg (150 lb)
Belt Restraint: 3-point belt
Airbag: not available

IMPACT INFORMATION

Case Vehicle A: 1990 Toyota Celica
Vehicle B: Buick 4-door sedan
Impact to Case Vehicle: angled frontal
Estimated Crash Severity: 24 to 48 kph (15 to 30 mph) EBS

VEHICLE DAMAGE

CDC: unknown
Maximum Crush: unknown
Vehicle Damage: unknown
Relevant Intrusions: unknown

NEONATAL OUTCOME

The pregnant occupant did not seek medical treatment immediately after the crash. The next day, she started bleeding vaginally. A placental abruption was suspected. One week after the crash, she delivered a 0.68 kg (1.5 lb) infant who died 1 hour after birth from premature delivery.

NEONATAL INJURIES

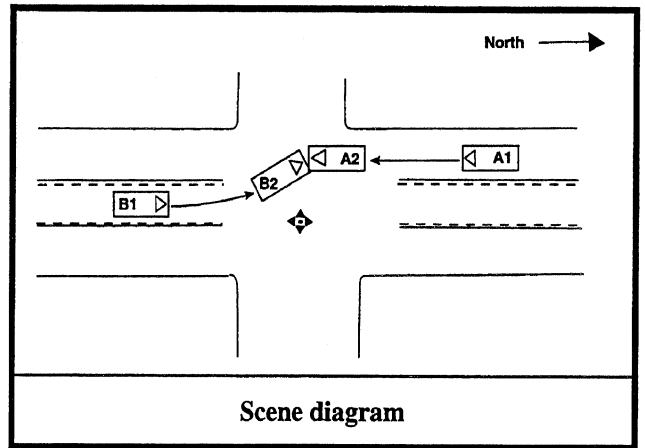
MAIS 0, ISS 0

The fetus died because it was prematurely delivered.

MATERNAL INJURIES

MAIS 3, ISS 9

<u>Body Part</u>	<u>Injury</u>	<u>AIS</u>	<u>Suspected Source</u>	<u>Suspected Mechanism</u>
placenta	abruption	3	lap belt	direct loading



Vehicle damage not available

**This case does not meet the criteria for a complete pregnancy crash investigation because the information came from a single interview with the subject. The vehicle was not inspected and medical records are not available.

GMP-209 CASE SUMMARY**

PREGNANT OCCUPANT

Position: driver
Gestational Age: 40 weeks
Maternal Age: 28 years
Stature: 157 cm (5' 2")
Mass: 100 kg (220 lb)
Belt Restraint: 3-point belt
Airbag: not available

IMPACT INFORMATION

Case Vehicle A: 1986 Saab 900
Vehicle B: 1996 Chevrolet S10 pickup
Impact to Case Vehicle: left side (near)
Estimated Crash Severity: < 24 kph (15 mph) EBS

VEHICLE DAMAGE

CDC: 08-LPAW-2
Estimated max. crush: 9 cm to left-rear door
Vehicle Damage: across left-side doors
Relevant Intrusions: unknown

NEONATAL OUTCOME

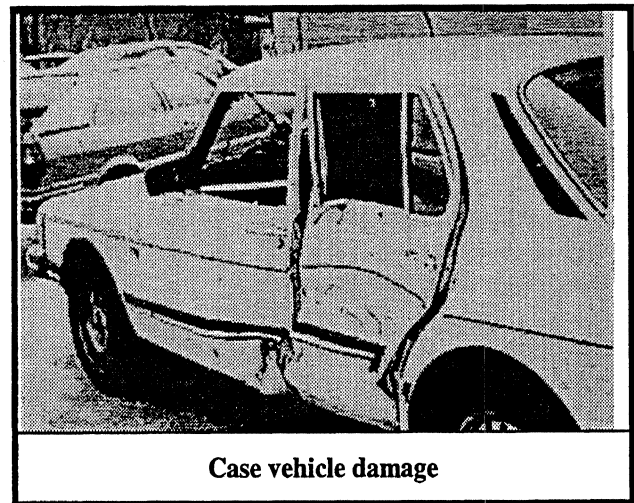
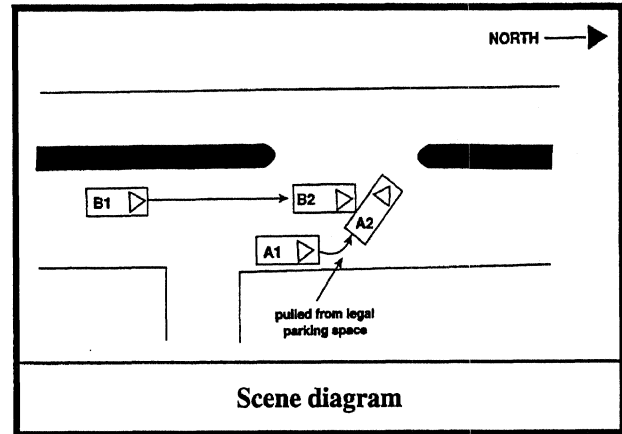
Initial diagnosis of the fetus was good. The pregnant occupant vaginally delivered a healthy 4.00 kg (8 lb 13 oz) baby 3 days after the crash at 40 weeks gestation. Apgar scores were 6 and 9 at 1 and 5 minutes, respectively.

NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 0, ISS 0



**This case does not meet the criteria for a complete pregnancy crash investigation because the vehicle was not inspected.

GMP-210 CASE SUMMARY**

PREGNANT OCCUPANT

Position: driver
Gestational Age: 37 weeks
Maternal Age: 31 years
Stature: 168 cm (5' 6")
Mass: 75 kg (165 lb)
Belt Restraint: 3-point belt
Airbag: did not deploy

IMPACT INFORMATION

Case Vehicle A: 1995 Saturn
Vehicle B: full-size pickup
Impact to Case Vehicle: rear
Estimated Crash Severity: < 24 kph (15 mph) EBS

VEHICLE DAMAGE

Estimated CDC: 06-BDEW-1
Estimated Max. Crush: minor
Vehicle Damage: across rear of vehicle
Relevant Intrusions: none

NEONATAL OUTCOME

Initial diagnosis of the fetus was good, although the pregnant driver experienced mild contractions that stopped without intervention. Nineteen days after the crash, the occupant delivered a 3.43 kg (7 lb 9 oz) infant of 40 weeks gestational age. Apgar scores were 9 and 9 at 1 and 5 minutes, respectively.

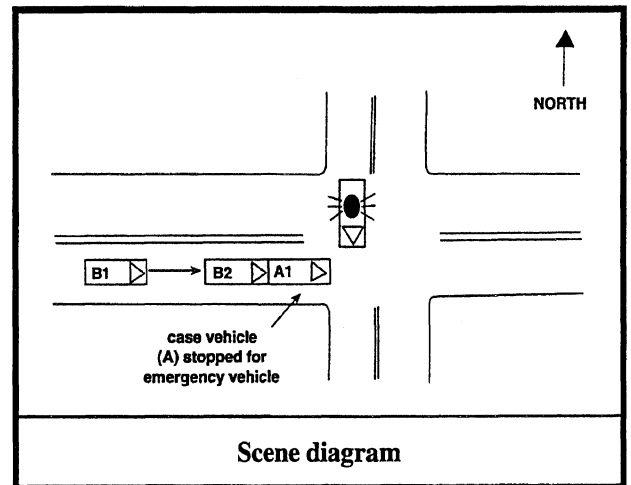
NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 1, ISS 1

<u>Body Part</u>	<u>Injury</u>	<u>AIS</u>	<u>Suspected Source</u>	<u>Suspected Mechanism</u>
cervical spine	strain	1	impact forces	inertial loading



Case vehicle damage not available

**This case does not meet the criteria for a complete pregnancy crash investigation because the vehicle was not inspected.

GMP-211 CASE SUMMARY**

PREGNANT OCCUPANT

Position: driver
Gestational Age: 39 weeks
Maternal Age: 26 years
Stature: 155 cm (5' 1")
Mass: 82 kg (180 lb)
Belt Restraint: 3-point belt
Airbag: deployed

IMPACT INFORMATION

Case Vehicle A: 1997 Dodge Grand Caravan
Vehicle B: 1989 Ford Mustang
Impact to Case Vehicle: frontal, then left side (near)
Crash Severity: 31 kph (19 mph) Delta V

VEHICLE DAMAGE

CDC: 11-FYEW-2, 09-LZEW-2
Maximum Crush: 61 cm to front corner
Vehicle Damage: across front and left side of vehicle
Relevant Intrusions: unknown

NEONATAL OUTCOME

Initial diagnosis of the fetus was good. The baby was delivered the day after the crash by planned cesarean section. Birth weight was 4.25 kg (9 lb 6 oz) and Apgar scores were 6 and 9 at 1 and 5 minutes, respectively.

NEONATAL INJURIES

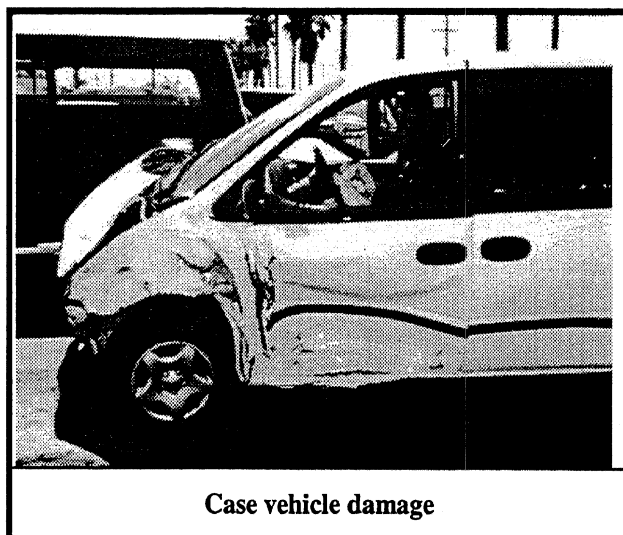
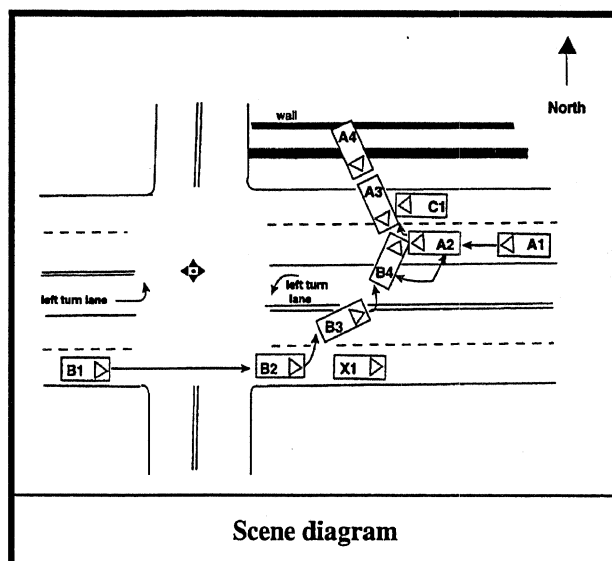
MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 2, ISS 9

<i>Body Part</i>	<i>Injury</i>	<i>AIS</i>	<i>Suspected Source</i>	<i>Suspected Mechanism</i>
shoulder, left a-c joint	dislocation	2	shoulder belt	direct loading
abdomen, mesentery	laceration	2	lap belt/steering wheel	direct loading
foot, right 1 st metatarsal	fracture	2	foot control	direct contact
various	abrasions	1	unknown	unknown
various	contusions	1	unknown	unknown

**This case does not meet the criteria for a complete pregnancy crash investigation because detailed vehicle damage measurements and interior contact areas were not available. The data were supplied by the UCSD CIREN investigation team.



GMP-212 CASE SUMMARY**

PREGNANT OCCUPANT

Position: right front
Gestational Age: 24 weeks
Maternal Age: 36 years
Stature: unknown
Mass: unknown
Belt Restraint: 3-point belt
Airbag: not available

IMPACT INFORMATION

Case Vehicle A: Ford Escort
Vehicle B: 1991 GMC Sonoma Pickup
Impact to Case Vehicle: right side (near)
Estimated Crash Severity: > 48 kph (30 mph) EBS

VEHICLE DAMAGE

CDC: unknown
Estimated Max. Crush: extensive
Vehicle Damage: across right side of vehicle
Est. Relevant Intrusions: unknown

NEONATAL OUTCOME

The fetus is assumed to have died as a result of maternal death.

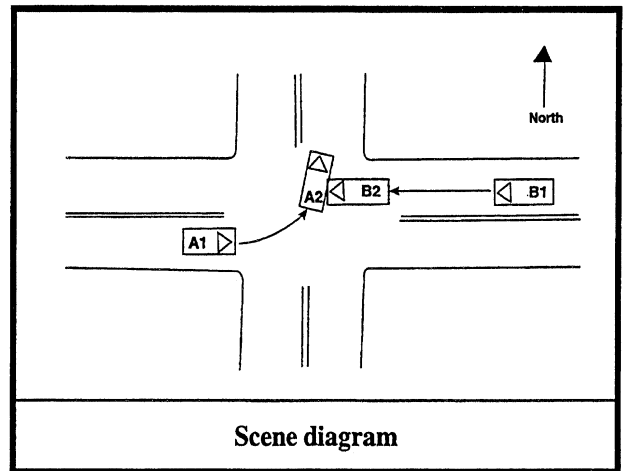
NEONATAL INJURIES

MAIS unknown, ISS unknown

MATERNAL INJURIES

MAIS 5, ISS 26

<u>Body Part</u>	<u>Injury</u>	<u>AIS</u>	<u>Suspected Source</u>	<u>Suspected Mechanism</u>
cervical spinal cord	transection	5	side door/shoulder belt	direct loading
cervical spine	odontoid fracture	3	side door/shoulder belt	direct loading
neck, right	abrasion	1	side door/shoulder belt	direct contact
jaw, right	abrasion	1	side door/shoulder belt	direct contact
chest, right	abrasion	1	side door/shoulder belt	direct contact
abdomen	abrasion	1	lap belt	direct contact



Vehicle damage not available

**This case does not meet the criteria for a complete pregnancy crash investigation because detailed vehicle damage information and interior contact areas were not available. The data were supplied by the UCSD CIREN investigation team.

GMP-213 CASE SUMMARY**

PREGNANT OCCUPANT

Position: driver
Gestational Age: 35 weeks
Maternal Age: 30 years
Stature: 165 cm (5' 5")
Mass: 96 kg (210 lb)
Belt Restraint: 3-point belt
Airbag: not available

IMPACT INFORMATION

Case Vehicle A: 1993 Jeep Grand Cherokee
Vehicle B: 1983 Chevrolet Citation
Impact to Case Vehicle: rear
Estimated Crash Severity: < 24 kph (15 mph) EBS

VEHICLE DAMAGE

CDC: not applicable
Maximum Crush: 0 cm
Vehicle Damage: none (hit trailer hitch)
Relevant Intrusions: none

NEONATAL OUTCOME

Initial diagnosis of the fetus was good, although the mother experienced abdominal cramping after the crash. A 3.83 kg (8 lb 7 oz) baby was delivered 7 weeks after the crash at a gestational age of 42 weeks. Apgar scores were 3 and 8 at 1 and 5 minutes, respectively, because the cord was wrapped around the infant's neck at birth. The infant was given oxygen and discharged in healthy condition.

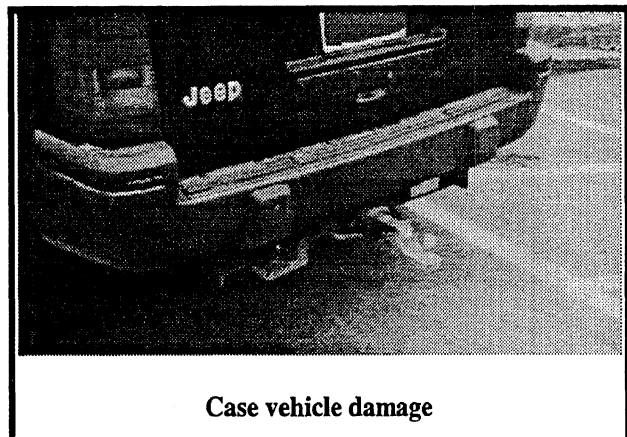
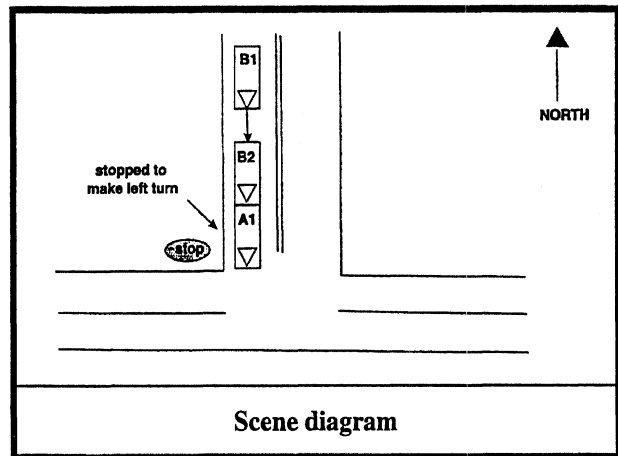
NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 0, ISS 0

**This case does not meet the criteria for a complete pregnancy crash investigation because there was no measurable vehicle damage available to estimate impact severity.



GMP-214 CASE SUMMARY**

PREGNANT OCCUPANT

Position: driver
Gestational Age: 36 weeks
Maternal Age: 37 years
Stature: unknown
Mass: unknown
Belt Restraint: automatic shoulder belt only
Airbag: deployed

IMPACT INFORMATION

Case Vehicle A: 1995 Ford Escort Station Wagon
Vehicle B: 1988 Acura Legend
Impact to Case Vehicle: offset frontal (55% vehicle overlap)
Crash Severity: 53 kph (33 mph) Delta V

VEHICLE DAMAGE

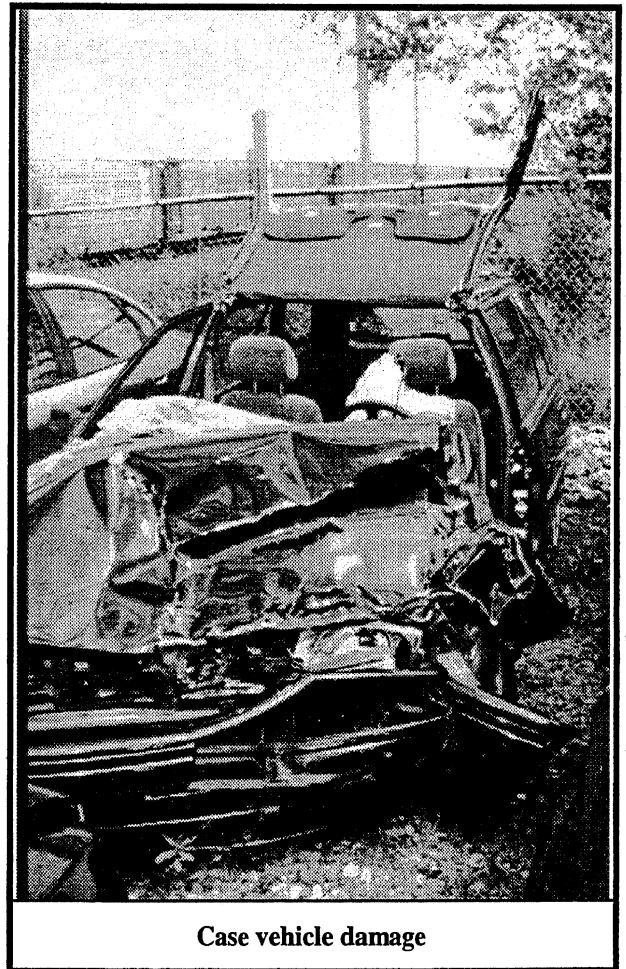
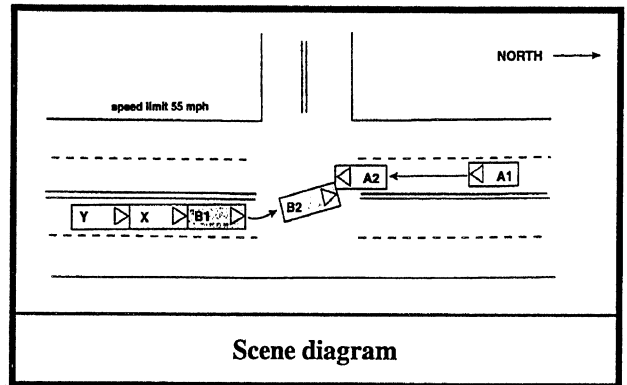
CDC: 12-FYEW-4
Maximum Crush: 81 cm to left-front bumper corner
Vehicle Damage: from left front bumper corner across front of vehicle
Relevant Intrusions: IP: 16 cm to rear
 steering column: 18 cm to rear
 toepan: 25 cm to rear

NEONATAL OUTCOME

The fetus died as a result of this crash. Placental abruption is suspected.

NEONATAL INJURIES

MAIS 0, ISS 0



MATERNAL INJURIES

MAIS unknown, ISS unknown

<i>Body Part</i>	<i>Injury</i>	<i>AIS</i>	<i>Suspected Source</i>	<i>Suspected Mechanism</i>
unknown	assumed to be moderately severe			

**This case does not meet the criteria for a complete pregnancy crash investigation because medical records were not available.

GMP-215 CASE SUMMARY**

PREGNANT OCCUPANT

Position: right rear
Gestational Age: 27 weeks
Maternal Age: 33 years
Stature: 173 cm (5' 8")
Mass: 61 kg (135 lb)
Belt Restraint: 3-point belt
Airbag: not available

IMPACT INFORMATION

Case Vehicle A: 1997 Dodge Intrepid
Vehicle B: 1986 Volkswagen Quantum
Vehicle C: 1997 Mazda 626
Impact to Case Vehicle: frontal, then rear
Estimated Crash Severity: < 24 kph (15 mph) EBS

VEHICLE DAMAGE

Estimated CDC: 12-FDEW-1, 06-BZLW-1
Estimated Max. Crush: minor
Vehicle Damage: across front of vehicle and right-rear bumper
Relevant Intrusions: none

NEONATAL OUTCOME

Initial diagnosis of the fetus was good, although the mother experienced abdominal cramping immediately after the crash. Twelve weeks after the crash, at a gestational age of 39 weeks, the pregnant occupant vaginally delivered a healthy 3.54 kg (7 lb 13 oz) infant.

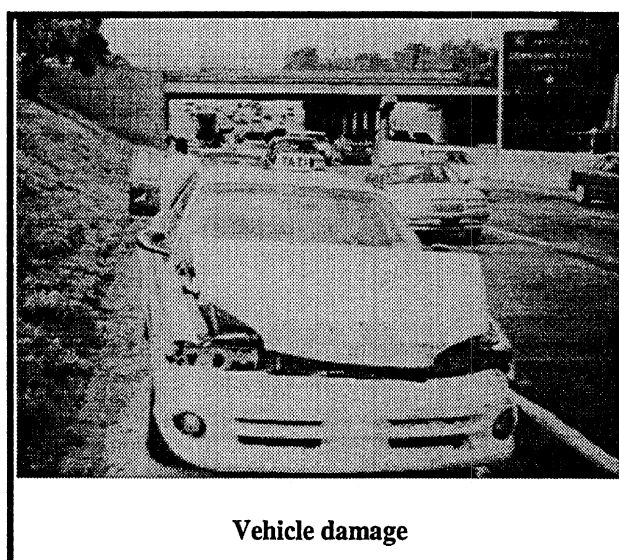
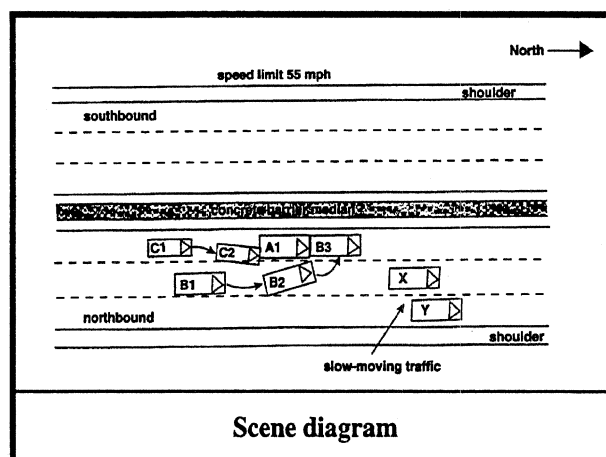
NEONATAL INJURIES

MAIS 0, ISS 0

MATERNAL INJURIES

MAIS 0, ISS 0

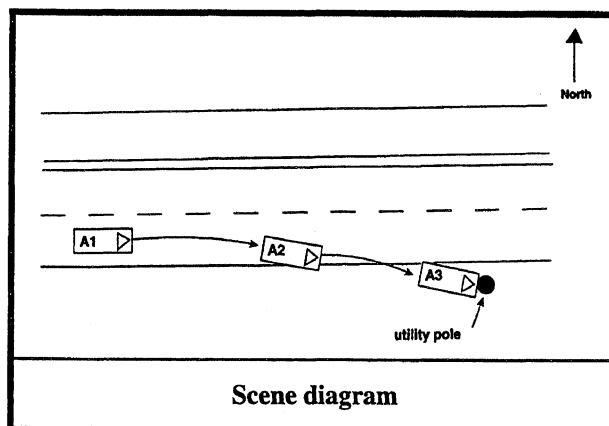
**This case does not meet the criteria for a complete pregnancy crash investigation because the vehicle interior could not be inspected.



GMP-216 CASE SUMMARY**

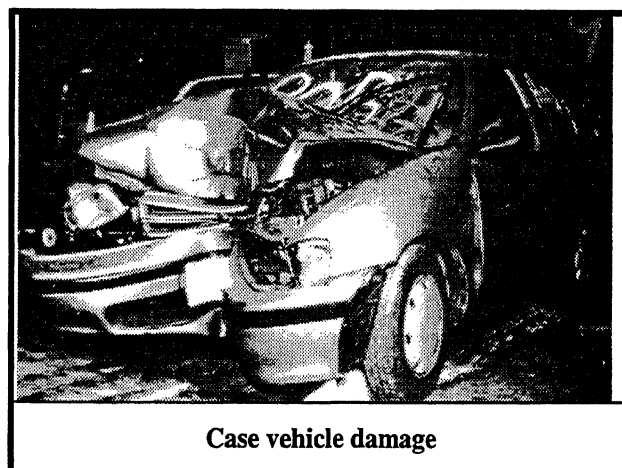
PREGNANT OCCUPANT

Position: driver
Gestational Age: 25 weeks
Maternal Age: 29 years
Stature: 157 cm (5' 2")
Mass: 52 kg (115 lb)
Belt Restraint: 3-point belt
Airbag: deployed



IMPACT INFORMATION

Case Vehicle A: 1993 Toyota Tercel
Vehicle B: none (pole)
Impact to Case Vehicle: frontal
Estimated Crash Severity: 24 to 48 kph (15 to 30 mph)



VEHICLE DAMAGE

Estimated CDC: 12-FCEN-4
Maximum Crush: unknown
Vehicle Damage: across front of vehicle
Est. Relevant Intrusions: minor

NEONATAL OUTCOME

The pregnant occupant started labor the day of the crash. The baby was delivered 3 days later at a gestational age of 25 weeks. Birth weight was 0.62 kg (1 lb 6 oz) and Apgar scores were 7 and 7 at 1 and 5 minutes, respectively. The infant had some episodes of apnea, head injuries most likely resulting from the crash, and neonatal respiratory distress syndrome.

NEONATAL INJURIES

MAIS 4, ISS 17

<u>Body Part</u>	<u>Injury</u>	<u>AIS</u>	<u>Suspected Source</u>	<u>Suspected Mechanism</u>
skin	contusions	1	unknown	unknown
brain	intraventricular hemorrhage	4	unknown	unknown
brain	intraparenchymal hematoma	4	unknown	unknown

MATERNAL INJURIES

MAIS 3, ISS 14

<u>Body Part</u>	<u>Injury</u>	<u>AIS</u>	<u>Suspected Source</u>	<u>Suspected Mechanism</u>
lower lip	laceration	1	airbag	direct contact
clavicle, left	fracture	2	shoulder belt	direct contact
placenta	abruption	3	steering wheel/3-pt belt	direct loading
knee, right	laceration	1	knee bolster	direct contact
knee, left medial	laceration	1	knee bolster	direct contact
foot, right talus	fracture	2	toe/pan, foot controls	direct contact
foot, right calcaneus	fracture	2	toe/pan, foot controls	direct contact

**This case does not meet the criteria for a complete pregnancy crash investigation because detailed vehicle damage measurements and interior contact areas were not available.