



ORIGINAL CONTRIBUTIONS

Pregnancy Outcomes following Hospitalization for Motor Vehicle Crashes in Washington State from 1989 to 2001

Melissa A. Schiff^{1,2} and Victoria L. Holt^{1,2,3}

¹ Harborview Injury Prevention and Research Center, Seattle, WA.

² Department of Epidemiology, School of Public Health and Community Medicine, University of Washington, Seattle, WA.

³ Division of Public Health Sciences, Fred Hutchinson Cancer Research Center, Seattle, WA.

Received for publication July 28, 2004; accepted for publication October 26, 2004.

This retrospective cohort study evaluated the risk of adverse pregnancy outcomes following motor vehicle crashes during pregnancy. The authors assessed outcomes of pregnant women hospitalized for motor vehicle crashes in Washington State from 1989 to 2001 ($n = 582$). They used the Injury Severity Score (ISS) to classify 84 severely injured (ISS ≥ 9), 309 non-severely injured (ISS 1–8), and 189 uninjured (ISS 0) pregnant women and compared them with pregnant women who had not been hospitalized for a motor vehicle crash ($n = 17,274$). Of pregnant women in motor vehicle crashes, 82.9% were hospitalized and discharged without delivering, and 17.1% delivered at hospitalization. Compared with women not in motor vehicle crashes, severely and non-severely injured women were at increased risk of placental abruption and cesarean delivery, and their infants were at increased risk of respiratory distress syndrome and fetal death. Uninjured women were also at increased risk of preterm labor (relative risk = 7.9, 95% confidence interval: 6.4, 9.8) and placental abruption (relative risk = 6.6, 95% confidence interval: 3.9, 11.2) compared with women not in motor vehicle crashes. Pregnant women hospitalized following motor vehicle crashes are at increased risk of adverse pregnancy outcomes, regardless of the presence or severity of injuries.

accidents, traffic; hospitalization; pregnancy outcome; wounds and injuries

Abbreviations: ICD-9-CM, *International Classification of Diseases*, Ninth Revision, Clinical Modification; ISS, Injury Severity Score.

Injury during pregnancy affects not only the pregnant woman but also her fetus and can result in adverse pregnancy outcomes. Unintentional injury complicates approximately 6 percent of all pregnancies (1), with the leading

mechanism of injury being motor vehicle crashes (2). Hyde et al. (3), utilizing a probability sample of police-reported US traffic crashes, estimated that 32,810 pregnant women are involved in motor vehicles crashes annually in the

Correspondence to Dr. Melissa A. Schiff, Harborview Injury Prevention and Research Center, 325 Ninth Avenue, Box 359960, Seattle, WA 98104 (e-mail: mschiff@u.washington.edu).

United States, for a crash rate of 9 per 1,000 livebirths. A recent study of all pregnant women involved in motor vehicle crashes in Utah noted that 2.8 percent experienced a crash during pregnancy (3). Prior studies have documented that motor vehicle crashes are one of the leading causes of injury-related maternal (4) and fetal (5) deaths. In addition to fatalities, motor vehicle crashes are the most common cause of injury-related hospitalizations of pregnant women (2).

Research on adverse pregnancy outcomes following motor vehicle crashes during pregnancy has been limited. Wolf et al. (6) utilized a large, retrospective cohort study design to evaluate the effect of seat-belt use on pregnancy outcome following a motor vehicle crash. Compared with restrained pregnant women, unrestrained pregnant women had a 2.3-fold increased risk of delivering a low-birth-weight infant (<2,500 g). Using a case series, Pearlman et al. (7) reported that 62 percent of improperly restrained women had adverse fetal outcomes compared with 27 percent of properly restrained women. Another case series of pregnant women in motor vehicle crashes documented that greater crash severity was associated with fetal death and that restraint use decreased the risk of adverse fetal outcomes (8). Because adverse pregnancy outcomes occur in the general population of pregnant women as well as in the population of pregnant women involved in motor vehicle crashes, it is important to evaluate the excess risk associated with these crashes. Although a recent study of pregnant motor vehicle occupants found no increased risk of adverse pregnancy outcomes among those in crashes compared with pregnant women not involved in motor vehicle crashes (3), the study did not evaluate outcomes stratified by injury severity. Our study evaluated the risk of adverse maternal and perinatal outcomes for pregnant women hospitalized following motor vehicle crashes, stratified by maternal injury severity.

MATERIALS AND METHODS

Study subjects

We conducted a retrospective cohort study to assess outcomes of pregnant women involved in motor vehicle crashes in Washington State from 1989 to 2001. By linking state birth and fetal death certificate data with hospital discharge data, we identified pregnant women hospitalized following a motor vehicle crash who experienced a singleton livebirth or fetal death. The hospital data were extracted from the Comprehensive Hospital Abstract Recording System from all Washington State nonfederal hospitals. Pregnant women in crashes were identified by the presence of an *International Classification of Diseases*, Ninth Revision, Clinical Modification (ICD-9-CM) external causation code (E code) of E810–E819 in the external injury field in the Comprehensive Hospital Abstract Recording System, indicating a motor vehicle traffic accident. We compared pregnant women involved in motor vehicle crashes with a randomly chosen group of pregnant women ($n = 17,274$) identified through the Washington State birth and fetal death certificate data who experienced a singleton livebirth or fetal death during the same time period but not a crash-related

hospitalization during pregnancy or a crash-related injury diagnosis at the delivery hospitalization. The sample size of the randomly chosen group of pregnant women was derived from a larger cohort study in which pregnant women who were uninjured were compared with pregnant women who experienced a range of injuries in addition to motor vehicle crashes in a ratio of three uninjured women to one injured woman. During the time period 1987–2001, Washington State recorded 1,024,079 livebirths and 5,695 fetal deaths. This study was approved by the University of Washington Institutional Review Board.

Exposure classification

We used ICD-9-CM diagnosis codes to classify types of injuries from motor vehicle crashes, as follows: fractures, dislocations, sprains, and strains (codes 800–849); intracranial injuries (codes 850–854); internal injuries to the chest (codes 860–862), abdomen (codes 863–866, 868), and pelvis (code 867); open wounds (codes 870–897); injury to blood vessels (codes 900–904); superficial injuries, contusions, and crushing injuries (codes 910–929); and nerve and spinal cord injuries (codes 950–957). Women with multiple types of injuries were classified as having all applicable injury types.

We evaluated the severity of crash-related injuries by using ICDMAP-90 computer software (Tri-Analytics Inc., Bel Air, Maryland) to determine the Injury Severity Score (ISS) (9). The ICDMAP-90 software assigns the ISS based on ICD-9-CM diagnosis codes in the hospitalization data. Of the 625 pregnant women involved in a motor vehicle crash, the ICDMAP-90 program was unable to assign an ISS for 43 because their injury diagnosis was not coded to a specific body region. These 43 women were excluded from the analyses of pregnancy outcomes. Of the remaining 582 pregnant women, 84 were classified as having severe injuries with an ISS of ≥ 9 , and 309 were classified as having nonsevere injuries with an ISS of 1–8. An ISS cutpoint of 9 was used because prior studies of pregnant trauma patients reported that this score predicted fetal death following injury during pregnancy (10, 11). The remaining 189 pregnant women experienced trauma (presence of an E code) but no injury (absence of an ICD-9-CM injury code) and were assigned an ISS of 0.

Outcome classification

To evaluate maternal and perinatal outcomes, we used the Washington State Birth Event Records Database, which contains the maternal and infant ICD-9-CM diagnosis and procedure codes for the delivery hospitalization, linked to the birth certificate or fetal death record. A prior study evaluating the linkage procedure for creating the Birth Event Records Database file reported that the linkage was 96 percent complete (12). Since 1980, the Washington State birth and fetal death certificates have included a checklist for obstetric procedures, method of delivery, complications of labor and delivery, and abnormal conditions of the newborn. Maternal outcomes investigated included the following: preterm labor at less than 37 weeks' gestation

(ICD-9-CM codes 644.0, 644.2 or use of tocolysis noted on the birth or fetal death certificate); premature rupture of membranes 24 hours or more prior to the onset of labor (ICD-9-CM code 658.2); placental abruption (ICD-9-CM code 641.2 or as listed on the birth or fetal death certificate); induction of labor (ICD-9-CM diagnosis codes 659.0, 659.1; procedure codes 73.1, 73.4, 96.49; or as listed on the birth or fetal death certificate); cesarean delivery (ICD-9-CM codes 74–74.2 or as listed on the birth or fetal death certificate); and maternal death (death of the mother during the hospitalization using the discharge status in the Comprehensive Hospital Abstract Recording System record).

Perinatal outcomes investigated included gestational age of less than 37 weeks (as recorded on the birth or fetal death certificate); low birth weight (<2,500 g listed on the birth or fetal death certificate); moderate-to-heavy meconium at delivery (noted on the birth or fetal death certificate); fetal distress (ICD-9-CM codes 656.3, 768.2–768.4 or as listed on the birth or fetal death certificate); mild-to-severe birth asphyxia (ICD-9-CM codes 768.5–768.9); and respiratory distress syndrome (ICD-9-CM code 769 or as listed on the birth certificate). We used an algorithm by Alexander et al. (13) to define small for gestational age as infant birth weight below the 10th percentile for a given gestational age, stratified on sex and race/ethnicity. We derived gestational age at the time of the motor vehicle crash by subtracting the number of weeks between the crash hospitalization and the birth/fetal death. We defined fetal death as an intrauterine death identified by a fetal death certificate.

Data analysis

We compared the demographic and obstetric characteristics of women hospitalized for a motor vehicle crash during pregnancy ($n = 625$) with those of women with no history of hospitalization for a motor vehicle crash during pregnancy ($n = 17,274$). We assessed proportions of types of injuries (using ICD-9-CM diagnosis codes) among the pregnant women in a motor vehicle crash who experienced severe and nonsevere injuries. We used Poisson regression analysis to calculate relative risks and 95 percent confidence intervals for associations between ISS categories and maternal and perinatal outcomes among those for whom data on pregnancy outcomes and confounding variables were complete. In our initial analyses, we built a regression model for each pregnancy outcome comparing all pregnant women involved in crashes with pregnant women who were not in crashes. Because we wanted to assess the differences in pregnancy outcomes stratified by ISS, we built additional regression models for each pregnancy outcome comparing pregnant women sustaining severe motor vehicle crash injuries (ISS ≥ 9), pregnant women experiencing nonsevere crash injuries (ISS 1–8), and pregnant women receiving no injuries in crashes (ISS 0) with pregnant women not involved in crashes.

We performed subanalyses of adverse pregnancy outcomes for the pregnant women in crashes who had no injuries (ISS 0), stratified by those who were hospitalized and subsequently discharged without delivering and those who delivered at their crash hospitalization. We assessed for possible interactions between ISS and gestational age and

found no significant interaction. We also assessed for possible confounding by age, race/ethnicity, marital status, education, income, gravidity, parity, prenatal smoking, type of prenatal care insurance, and trimester that prenatal care was initiated. Relative risks were adjusted for age and prenatal smoking because these factors were associated with both motor vehicle crash exposure and maternal and perinatal outcomes and changed one or more of the relative risks by at least 10 percent. For selected maternal and perinatal outcomes for which there were fewer than five observations among the injured women, we present unadjusted relative risks in this paper. All statistical analyses were performed by using Stata version 8.0 software (Stata Corporation, College Station, Texas).

RESULTS

We found that 625 pregnant women were hospitalized following motor vehicle crashes in Washington State between 1989 and 2001, resulting in an incidence rate of 0.61 pregnant crash hospitalizations per 1,000 livebirths. Of these women, 518 (82.9 percent) were hospitalized and subsequently discharged without delivering, and 107 (17.1 percent) delivered during their crash hospitalization. The majority of pregnant women in crashes were in their third trimester (65.9 percent), with 18.4 percent in the second trimester and 15.7 percent in the first trimester. Compared with pregnant women not involved in crashes, pregnant women in crashes were younger and more likely to be non-White, be unmarried, and have Medicaid for their prenatal care insurance (table 1). Pregnant women in crashes also had lower educational levels and were more likely to use tobacco and consume alcohol prenatally, initiate prenatal care after the first trimester, and deliver prematurely.

For the pregnant women involved in motor vehicle crashes, we compared the types of injuries among the severely injured (ISS ≥ 9 , $n = 84$) and the non-severely injured (ISS 1–8, $n = 309$). Compared with non-severely injured pregnant women, pregnant women with severe injuries were more likely to have fractures, dislocations, and sprains; intracranial injuries; open wounds; and internal injuries of the chest, abdomen, and pelvis (table 2). We identified 189 pregnant women (30.2 percent) who had been in a motor vehicle at the time of a crash but had no injuries documented at their injury hospitalization (ISS 0).

Compared with pregnant women not involved in motor vehicle crashes, pregnant women involved in crashes were at significantly increased risk of preterm labor (relative risk = 4.5, 95 percent confidence interval: 3.9, 5.3), placental abruption (relative risk = 6.0, 95 percent confidence interval: 4.3, 8.2), and cesarean delivery (relative risk = 1.3, 95 percent confidence interval: 1.1, 1.5). Their infants were at increased risk of preterm delivery (relative risk = 1.4, 95 percent confidence interval: 1.1, 1.9) and infant respiratory distress syndrome (relative risk = 2.6, 95 percent confidence interval: 1.6, 4.2).

Stratifying our analysis by ISS, we found that severely injured pregnant women (ISS ≥ 9) had a 1.6-fold increased risk of cesarean delivery and a ninefold increased risk of

TABLE 1. Demographic and obstetric characteristics of pregnant women not involved in a motor vehicle crash and those involved in crashes in Washington State, 1989–2001

	Pregnant, no motor vehicle crash* (n = 17,274)		Pregnant, motor vehicle crash* (n = 625)	
	No.	%	No.	%
Age (years)				
<20	1,921	11.1	134	21.5
20–34	13,191	76.4	431	69.0
≥35	2,154	12.5	59	9.5
Race/ethnicity				
Non-Hispanic White	12,936	77.4	403	66.4
Black	580	3.5	76	12.5
Asian	1,121	6.7	59	9.7
American Indian	404	2.4	22	3.6
Hispanic White	1,675	10.0	47	7.8
Education (no. of years)				
<12	2,089	18.4	105	26.3
12	3,670	32.3	153	38.4
>12	5,602	49.3	141	35.3
Marital status				
Single	4,640	26.9	315	50.5
Married	12,587	73.1	309	49.5
Median family census income				
<\$25,000	3,008	28.4	127	33.7
\$25,000–\$35,000	4,364	41.3	154	40.9
≥\$35,001	3,207	30.3	96	25.4
Prenatal insurance				
Medicaid	4,188	35.6	220	52.2
Self/charity	232	2.0	3	0.7
Commercial	6,530	55.4	171	40.5
Other	827	7.0	28	6.6
Prenatal smoking				
No	13,535	83.0	424	76.3
Yes	2,779	17.0	132	23.7
Prenatal alcohol consumption				
No	8,452	94.6	254	92.0
Yes	479	5.4	22	8.0
Gravidity				
1	5,607	32.5	210	33.6
2	4,796	27.7	141	22.6
≥3	6,866	39.8	274	43.8
Parity				
1	7,098	41.9	282	45.9
2	5,567	32.8	163	26.5
≥3	4,294	25.3	170	27.6
Trimester during which prenatal care was initiated				
1	13,193	81.8	411	73.5
2	2,446	15.2	123	22.0
3	484	3.0	25	4.5
Gestational age at delivery (weeks)				
<28	92	0.5	7	1.1
28–32	202	1.2	16	2.6
33–36	1,067	6.3	59	9.6
≥37	15,700	92.0	533	86.7

* Some column numbers do not add to total because of missing information.

TABLE 2. Types of injuries sustained, stratified by injury severity, by women hospitalized for a motor vehicle crash in Washington State, 1989–2001

ICD-9-CM* injury classification	Nonsevere injury (n = 309)†		Severe injury (n = 84)†	
	No.	%	No.	%
Fractures, dislocations, sprains	165	53.4	68	81.0
Intracranial injuries	30	9.7	21	25.0
Internal injury of chest	0	0	22	26.2
Internal injury of abdomen	9	2.9	17	20.2
Internal injury of pelvis	3	1.0	2	2.4
Open wound	54	17.5	35	41.7
Blood vessel injury	1	0.3	3	3.6
Superficial, contusion, crushing injury	165	53.4	22	26.2
Nerve and spinal cord injuries	1	0.3	1	1.2

* ICD-9-CM, *International Classification of Diseases*, Ninth Revision, Clinical Modification.

† Types of injuries add to >100% because some pregnant women in crashes had more than one type of injury.

placental abruption compared with pregnant women not involved in motor vehicle crashes (table 3). Two (2.4 percent) of the severely injured pregnant women died in crashes compared with two (0.01 percent) of the pregnant women not in crashes. The risk of adverse perinatal outcomes was also increased for the severely injured pregnant women, with a twofold increased risk of fetal distress, a fourfold increased risk of infant respiratory distress syndrome, and a ninefold increased risk of fetal death. Non-severely injured pregnant women (ISS 1–8) were at increased risk of preterm labor, placental abruption, and cesarean delivery compared with pregnant women not involved in a motor vehicle crash.

We found that pregnant women involved in crashes who had no documented injuries (ISS 0) were at a marked increased risk of preterm labor and placental abruption and that their infants were at an increased risk of preterm delivery, low birth weight, and infant respiratory distress syndrome compared with pregnant women not involved in motor vehicle crashes (table 3). We further stratified our analysis of outcomes among uninjured pregnant women involved in crashes by timing of the crash in relation to delivery (table 4). We found that uninjured women who were hospitalized for motor vehicle crashes and who were discharged without delivering were at a ninefold increased risk of preterm labor and a sixfold increased risk of placental abruption. Pregnant women involved in crashes who delivered during the crash hospitalization were also at increased risk of preterm labor and abruption and, for their infants, preterm delivery, low birth weight, being small for their gestational age, and infant respiratory distress syndrome.

DISCUSSION

In this population-based study, one third of pregnant women hospitalized after a motor vehicle crash had no reported injuries, one half had nonsevere injuries, and only one in seven had injuries classified as severe. Although severely injured pregnant women were at increased risk of adverse pregnancy outcomes, non-severely injured pregnant women involved in crashes were also at significantly

increased risk of preterm labor, placental abruption, and cesarean delivery.

Although prior studies (14, 15) have noted that crash severity is related to adverse outcomes, with more-severe crashes resulting in more-severe injuries and adverse pregnancy outcomes, less-severe crashes also have the potential for adverse outcomes. Among pregnant women involved in crashes who sustained nonsevere injuries, our findings of increased risks of preterm labor, placental abruption, and cesarean delivery confirm those from earlier non-population-based studies. In the case series by Klinich et al. (8), 41 of 120 pregnant women involved in crashes experienced placental abruption with only minor maternal injuries. Several other studies of noncatastrophic trauma during pregnancy have reported preterm labor (16, 17), placental abruption (16, 17), and cesarean section (18) in case series of non-severely injured pregnant women. These studies of noncatastrophic injuries could not determine the magnitude of any potential association between injury and outcomes because of a lack of comparison groups of uninjured pregnant women. Our findings of adverse outcomes among non-severely injured pregnant women involved in crashes indicate that relatively minor trauma can have a substantial impact on pregnancy outcomes. Our findings also illustrate that the ISS in pregnancy is a poor predictor of adverse pregnancy outcomes, as documented in a prior study of the use of ISS scores to predict adverse pregnancy outcomes (19). It may be useful to develop an injury severity scoring system specific to pregnancy to evaluate patients who experience trauma during pregnancy.

We found that, compared with pregnant women not involved in crashes, pregnant women hospitalized with no reported injuries after motor vehicle crashes were at increased risk of adverse pregnancy outcomes including preterm labor, placental abruption, and infant respiratory distress syndrome. The increased risk of preterm labor may be explained by the forces of the crash stimulating uterine contractions, although the biomechanics of crash forces on the contractility of the pregnant uterus have not been studied to our knowledge. Placental abruption in uninjured pregnant

TABLE 3. Maternal and perinatal outcomes following a motor vehicle crash, stratified by Injury Severity Score, in Washington State, 1989–2001

Pregnancy outcome	No motor vehicle crash (n = 17,274)			Severe injury: ISS* (≥9) (n = 84)			Nonsevere injury: ISS 1–8 (n = 309)			Uninjured: ISS 0 (n = 189)					
	No.	%		No.	%	RR†, ‡	95% CI*	No.	%	RR†	95% CI	No.	%	RR†	95% CI
Preterm labor	1,143	6.6		11	13.1	1.6	0.8, 3.0	76	24.6	3.4	2.6, 4.4	97	51.3	7.9	6.4, 9.8
Premature rupture of membranes	347	2.0		1	1.2	0.6‡	0.1, 4.2	7	2.3	0.9	0.4, 2.2	5	2.7	1.6	0.7, 3.8
Placental abruption	248	1.4		11	13.1	9.0	4.7, 17.0	23	7.4	4.8	3.0, 7.6	16	8.5	6.6	3.9, 11.2
Labor induction	4,068	23.6		13	15.5	0.7	0.4, 1.2	71	23.0	1.0	0.8, 1.3	46	24.3	1.0	0.7, 1.4
Cesarean delivery	3,367	19.5		26	31.0	1.6	1.1, 2.4	77	25.0	1.3	1.0, 1.6	45	23.8	1.3	0.9, 1.8
							<i>Maternal</i>								
Gestational age <37 weeks	1,370	8.0		121	5.0	1.6	0.8, 3.1	37	12.1	1.1	0.8, 1.8	26	13.9	1.6	1.0, 2.6
Birth weight <2,500 g	765	4.4		8	9.8	1.4	0.6, 3.2	19	6.2	1.1	0.6, 1.8	18	9.5	1.8	1.0, 3.1
Small for gestational age	1,230	9.3		6	10.3	1.0	0.4, 2.1	20	9.1	0.9	0.6, 1.4	19	14.7	1.4	0.9, 2.3
Meconium at delivery	962	6.1		5	6.7	1.1	0.5, 2.7	15	5.4	0.9	0.6, 1.6	17	9.8	1.5	0.9, 2.5
Fetal distress	1,621	9.4		17	20.2	2.1	1.3, 3.5	37	12.0	1.2	0.8, 1.7	23	12.2	1.1	0.7, 1.8
Hypoxia	243	1.4		1	1.2	0.8‡	0.1, 6.0	8	2.6	1.6	0.7, 3.5	4	2.1	1.5‡	0.6, 4.0
Respiratory distress syndrome	209	1.2		5	6.0	3.8	1.4, 10.2	7	2.3	1.4	0.6, 3.5	7	3.7	3.0	1.3, 6.8
Fetal death	47	0.3		2	2.5	9.0‡	2.1, 37.1	5	1.6	1.3	0.2, 9.8	0			

* ISS, Injury Severity Score; RR, relative risk; CI, confidence interval.

† Adjusted for age and prenatal smoking.

‡ Unadjusted.

women involved in crashes was also reported by Klinich et al. (8) in a large case series of 120 pregnant women in crashes, 10 of whom experienced placental abruption with no maternal injuries. Biomechanical studies of uterine and placental tissue and finite-element modeling of the pregnant uterus have documented that the shear forces of the crash impact can cause the placenta to separate from the uterus (7). Another study using finite-element modeling of the pregnant uterus reported that contact with the steering wheel resulted in strain at the uteroplacental interface sufficient to cause placental abruption (20). Although we found no fetal deaths among the uninjured pregnant women involved in crashes, a case series of pregnant trauma patients by Poole et al. (21) included five uninjured pregnant women who experienced a fetal death. Our findings of adverse outcomes for pregnant women in crashes with no documented injuries indicate that crashes resulting in no maternal injuries can increase the risk of adverse pregnancy outcomes. Since our study included only those pregnant women who were hospitalized following motor vehicle crashes, there was the potential for selection bias; those women who had adverse obstetric or fetal signs such as contractions, uterine tenderness, vaginal bleeding, or fetal distress may have been more likely to be hospitalized despite having no crash-related injuries. Because we used existing databases and did not evaluate medical records, it was difficult to determine the exact chain of events following a motor vehicle crash.

Our study had several limitations. The most important was that our data were limited to pregnant women who were hospitalized following a crash. By limiting our study to these women, we likely included pregnant women who sustained more-severe injuries and those who were at increased risk of adverse outcomes and excluded pregnant women who experienced more minor injuries and those not at increased risk of adverse outcomes. These exclusions could possibly result in overestimation of the magnitude of risk of adverse pregnancy outcomes following a motor vehicle crash. In addition, our finding that over half of the pregnant women were in their third trimester of pregnancy is also likely explained by the selection of hospitalized subjects. A significant proportion of women in a crash during their third trimester would seek care at a hospital for fetal assessment. Women in their first trimester and the early part of their second trimester would not require fetal monitoring because the fetus would be pre-viable. A prior study of pregnant women in crashes that used police crash reports rather than hospitalizations to identify subjects noted a more uniform distribution of crashes by trimester (3).

Since the ISS was initially developed to predict survival following motor vehicle crashes in a nonpregnant population (9), and a prior study has shown that the ISS is a poor predictor of adverse outcomes among injured pregnant women (19), its use in our pregnant cohort may have resulted in misclassification of the severity of injury or the impact of the injury on the pregnancy. Despite these limitations, we used the ISS to classify injury severity because other studies have used it as a standardized measurement in pregnant as well as nonpregnant populations and a pregnancy-specific injury scoring system is not available. Our results may have been biased by differential

TABLE 4. Maternal and perinatal outcomes among uninjured women following a motor vehicle crash, stratified by timing of crash hospitalization in relation to delivery, Washington State, 1989–2001

Pregnancy outcome	No motor vehicle crash (<i>n</i> = 17,274)		Motor vehicle crash hospitalization prior to delivery: ISS* 0 (<i>n</i> = 151)				Motor vehicle crash hospitalization at delivery: ISS 0 (<i>n</i> = 38)			
	No.	%	No.	%	RR*,†	95% CI*	No.	%	RR†	95% CI
<i>Maternal</i>										
Preterm labor	1,143	6.6	89	58.9	9.0	7.2, 11.3	8	21.1	3.3	1.6, 6.9
Premature rupture of membranes	347	2.0	3	2.0	1.0‡	0.3, 3.1	2	5.3	2.6‡	0.7, 10.5
Placental abruption	248	1.4	12	7.8	6.6	3.7, 11.9	4	10.5	7.3‡	2.7, 19.7
Labor induction	4,068	23.6	36	23.8	1.0	0.7, 1.4	10	26.3	1.2	0.6, 2.3
Cesarean delivery	3,367	19.5	32	21.2	1.2	0.8, 1.7	13	34.2	1.8	1.0, 3.3
<i>Perinatal</i>										
Gestational age <37 weeks	1,370	8.0	14	9.4	1.4	0.8, 2.4	7	18.4	2.9	1.3, 6.4
Birth weight <2,500 g	765	4.4	7	4.6	0.8	0.3, 2.0	11	29.0	5.9	2.9, 11.9
Small for gestational age	1,230	9.3	11	11.2	1.1	0.6, 2.1	8	25.8	2.4	1.1, 5.4
Meconium at delivery	962	6.1	15	11.0	1.7	1.0, 3.0	2	5.6	0.9‡	0.2, 3.7
Fetal distress	1,621	9.4	14	9.3	0.9	0.5, 1.7	9	23.7	2.1	0.9, 4.6
Hypoxia	243	1.4	4	2.7	1.9‡	0.5, 5.3	0			
Respiratory distress syndrome	209	1.2	4	2.7	2.2‡	0.8, 5.9	3	7.9	6.5‡	2.1, 20.4
Fetal death	47	0.3	0				0			

* ISS, Injury Severity Score; RR, relative risk; CI, confidence interval.

† Adjusted for age and prenatal smoking.

‡ Unadjusted.

ascertainment of maternal and infant outcomes. Increased awareness of possible adverse outcomes following a crash may have resulted in differential reporting of certain subjective diagnoses (e.g., placental abruption, fetal distress, and infant respiratory distress syndrome) on the birth and fetal death certificates for the pregnant women in crashes compared with the pregnant women not involved in a crash. The more-objective diagnoses we examined (gestational age, birth weight, and fetal death) were not subject to this potential bias.

Limitations of coding and data entry in the Comprehensive Hospital Abstract Recording System and on the birth and fetal death certificates may have limited our ability to accurately ascertain demographic, exposure, and outcome information. Studies have documented that birth weight, race, age, and number of prior livebirths are recorded on birth and fetal death certificates with nearly complete accuracy (22), but prenatal and intrapartum complications, delivery method, and obstetric procedures are recorded less accurately (23, 24). Prior studies have also evaluated the accuracy of ICD-9-CM coding for selected obstetric diagnosis and procedure codes comparing discharge databases with medical records and have noted good-to-excellent accuracy (25, 26). We attempted to minimize inaccuracies by using multiple sources to identify specific maternal and perinatal outcomes when possible. Nondifferential misclassification of outcomes would have resulted in spurious attenuation of our risk estimates. We were also unable to evaluate pregnancy outcomes prior to 20 weeks' gestation because birth and fetal death certificates are used for pregnancies of more than 20 weeks only. Although it has

been well documented that seat-belt use during pregnancy decreases the risk of adverse pregnancy outcomes (6, 27), we did not have information on seat-belt use or airbag deployment in our pregnant cohort.

In conclusion, we found that pregnant women hospitalized following motor vehicle crashes are at increased risk of adverse pregnancy outcomes, regardless of the presence of documented injuries or the severity of the injury. In light of the increased risk of adverse maternal and perinatal outcomes resulting from trauma due to crashes without injuries, careful maternal and fetal monitoring following a crash is warranted. Future studies evaluating police crash data in conjunction with birth and fetal death certificates and hospitalization data may provide additional insight into how specific types of crashes and crash forces play a role in adverse pregnancy outcomes. Additional biomechanical and clinical research will also provide much needed information on the effects of motor vehicle crashes during pregnancy.

ACKNOWLEDGMENTS

This research was supported by grant R49/CCR002570-18 from the Centers for Disease Control and Prevention, Atlanta, Georgia.

The authors thank William O'Brien for supplying the data analysis files and Chris Mack at the Harborview Injury Prevention and Research Center for providing the injury severity scores by using the ICDMAP-90 software.

REFERENCES

1. Patterson RM. Trauma in pregnancy. *Clin Obstet Gynecol* 1984;27:32–8.
2. Weiss HB. Pregnancy-associated injury hospitalizations in Pennsylvania, 1995. *Ann Emerg Med* 1999;34:626–36.
3. Hyde LK, Cook LJ, Olson LM, et al. Effect of motor vehicle crashes on adverse fetal outcomes. *Obstet Gynecol* 2003; 102:279–86.
4. Schiff M, Albers L, McFeeley P. Motor vehicle crashes and maternal mortality in New Mexico: the significance of seat belt use. *West J Med* 1997;167:19–22.
5. Weiss HB, Songer TJ, Fabio A. Fetal deaths related to maternal injury. *JAMA* 2001;286:1863–8.
6. Wolf ME, Alexander BH, Rivara FP, et al. A retrospective cohort study of seatbelt use and pregnancy outcome after motor vehicle crash. *J Trauma* 1993;34:116–19.
7. Pearlman MD, Klinich KD, Schneider LW, et al. A comprehensive program to improve safety for pregnant women and fetuses in motor vehicle crashes: a preliminary report. *Am J Obstet Gynecol* 2000;182:1554–64.
8. Klinich KD, Schneider LW, Moore JL, et al. Investigations of crashes involving pregnant occupants. Proceedings: 44th Annual Conference of the Association for the Advancement of Automotive Medicine, Chicago, Illinois, October 2–4, 2000:37–55.
9. Baker SP, O'Neill B, Haddon W, et al. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma* 1974;14:187–96.
10. Theodorou DA, Velmahos GC, Souter I, et al. Fetal death after trauma in pregnancy. *Am Surg* 2000;66:809–12.
11. Kissinger DP, Rozycki GS, Morris JA, et al. Trauma in pregnancy—predicting pregnancy outcome. *Arch Surg* 1991;126:1079–86.
12. Hohner V, Armstrong R. Birth Event Records Project: developing a permanent linked database. Olympia, WA: Washington State Department of Health, April 1991.
13. Alexander GR, Kogan MD, Himes JH. 1994–1996 U.S. singleton birth weight percentiles for gestational age by race, Hispanic origin, and gender. *Matern Child Health J* 1999; 3:225–31.
14. Reis PM, Sander M, Pearlman MD. Abruptio placentae after auto accidents: a case control study. *J Reprod Med* 2000;45: 6–10.
15. Klinich KD, Schneider LW, Moore JL, et al. Investigations of crashes involving pregnant occupants. Ann Arbor, MI: Michigan University, Transportation Research Institute, Biosciences Division and Michigan University Medical School, 1999. (Report no. UMTRI-99-29).
16. Dahmus MA, Sibai BM. Blunt abdominal trauma: are there any predictive factors for abruptio placenta or maternal-fetal distress? *Am J Obstet Gynecol* 1993;169:1054–9.
17. Goodwin TM, Breen MT. Pregnancy outcome and fetomaternal hemorrhage after noncatastrophic trauma. *Am J Obstet Gynecol* 1990;162:665–71.
18. Morris JA, Rosenbower TJ, Jurkovich GJ, et al. Infant survival after cesarean section for trauma. *Ann Surg* 1996;223:481–91.
19. Schiff MA, Holt VL. The injury severity score in pregnant trauma patients: predicting placental abruption and fetal death. *J Trauma* 2002;53:946–9.
20. Moorcroft DM, Jernigan MV, Duma SM, et al. A finite element model of the pregnant female occupant: analysis of injury mechanisms and restraint systems. Proceedings: 48th Annual Conference of the Association for the Advancement of Automotive Medicine, Key Biscayne, Florida, September 13–15, 2004:347–51.
21. Poole GV, Martin JN, Perry KG, et al. Trauma in pregnancy: the role of interpersonal violence. *Am J Obstet Gynecol* 1996;174:1873–8.
22. Schoendorf KC, Parker JD, Batkhan LZ, et al. Comparability of the birth certificate and the 1988 Maternal and Infant Health Survey. *Vital Health Stat* 2 1993;Mar:1–19.
23. Parrish KM, Holt VL, Connell FA, et al. Variations in the accuracy of obstetric procedures and diagnoses on birth records in Washington State, 1989. *Am J Epidemiol* 1993;138:119–27.
24. Dobie SA, Baldwin LM, Rosenblatt RA, et al. How well do birth certificates describe the pregnancies they report? The Washington State experience with low-risk pregnancies. *Matern Child Health J* 1998;2:145–54.
25. Geller SE, Ahmed S, Brown ML, et al. International Classification of Diseases-9th revision coding for preeclampsia: how accurate is it? *Am J Obstet Gynecol* 2004;190:1629–33.
26. Korst LM, Gregory KD, Gornbein JA. Elective primary caesarean delivery: accuracy of administrative data. *Pediatr Perinatal Epidemiol* 2004;18:112–19.
27. Crosby WM, Costiloe JP. Safety of lap-belt restraint for pregnant victims of automobile collisions. *N Engl J Med* 1971;284:632–6.