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Papers presented

Long-term fetal outcomes in pregnant trauma patients

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Abstract

Background: Trauma during pregnancy is associated with significant maternal and fetal morbidity and mortality, typically occurring during the hospital admission. Less is known about the delayed effects of trauma on pregnancy outcome once the patient has been discharged from the hospital with a viable fetus.
Methods: A retrospective cohort study was conducted of pregnant trauma patients who were discharged from the trauma center with a viable fetus. Risk of preterm delivery (PTD) and low birth weight (LBW) were compared between injured patients (Injury Severity Score $>$ 0) and those without identified injury (Injury Severity Score $=$ 0), for the remainder of pregnancy.
Results: Even after trauma center discharge, injured patients had a nearly 2-fold higher risk of PTD (relative risk, 1.9; 95% confidence interval, 1.1–3.3) and LBW (relative risk, 1.8; 95% confidence interval, 1.04–3.2) for the remainder of the pregnancy. The risk was higher with increasing injury severity and among those injured early in gestation.
Conclusion: The risk of PTD and LBW in pregnant trauma patients who were discharged from trauma centers with a viable fetus remains increased throughout the remainder of the pregnancy. A history of trauma during gestation is a risk factor for poor pregnancy outcome.

Keywords: Trauma; Pregnancy; Injury; Delayed; Preterm delivery; Low birth weight

Trauma during pregnancy is a major cause of maternal and fetal morbidity and mortality, and occurs in up to 7% of all pregnancies [1–3]. It is the leading cause of maternal mortality throughout gestation and has been proven to account for at least 5% of all fetal deaths [4,5]. The majority of the literature has focused on fetal outcomes during the trauma center admission. Trauma-related factors known to be associated with increased fetal mortality include maternal death, maternal Injury Severity Score (ISS), severe abdominal injury, presence of shock, gestational age (GA) at the time of trauma, presence of consumptive coagulopathy, and ejection mechanism of injury [6–9].

Information about the effects of trauma throughout the remainder of the pregnancy is sketchy and conflicting because many pregnant trauma patients who are discharged from trauma centers with viable fetuses are lost to follow-up evaluation [9]. Earlier studies using retrospective case-control designs have been inconclusive because of inadequate sample size or incomplete follow-up evaluation to rule out a delayed effect of trauma on pregnancy outcome [8,10–12]. Others have alluded to higher complications at delivery in patients with a history of trauma earlier in gestation, but incorporate significant bias by comparing pregnant trauma patients with pregnant nontrauma controls [13,14]. It is assumed that risk factors associated with adverse pregnancy outcomes are distributed equally among groups when pregnant trauma patients are compared with those without history of trauma.

The purpose of the current analysis was to determine the effects of maternal trauma on fetal outcomes during the remainder of the pregnancy, after the patient has been discharged from the trauma center with a viable fetus. Only patients who required trauma center admission were used

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for comparison, thus minimizing the selection bias associated with prior studies. Delayed pregnancy outcomes such as preterm delivery (PTD) and low birth weight (LBW) are major determinants of neonatal morbidity and mortality [15–17]. Our specific hypothesis was that trauma during pregnancy places the fetus at risk for complications throughout the remainder of the pregnancy and, hence, a history of trauma during gestation should be considered a risk factor for poor pregnancy outcome.

Methods

A 10-year retrospective cohort study was performed at a large (4,500 admissions/y, 15% with ISS > 15), urban, level I trauma center with a concomitant, high-volume, obstetric service (1995–2004). Pregnancy testing is performed on all women who present to the trauma center of child-bearing age using a standard urine β-human chorionic gonadotropin test. Institutional protocol requires all pregnant trauma patients to be evaluated by the obstetric service. Those patients with a GA of 24 weeks or more are evaluated immediately by the obstetrics service while in the emergency department. Women are admitted for management of injuries or serial examinations because of concern for possible injuries, or are observed and undergo a minimum of 6 hours of fetal monitoring (GA ≥ 24 wk). Patients may be discharged once injuries have been treated or ruled out by the trauma service, and the fetus is deemed viable and stable by the obstetric service. During the study period, 1,005 pregnant patients were admitted to the trauma service following this protocol. Of these, 901 patients ultimately gave birth at our institution (follow-up rate, 90%), and were identified by linking the trauma registry to the obstetric service's pregnancy outcome database. Twin pregnancies (n = 2), because of associated higher risks of fetal complications [18], and patients with incomplete data were excluded from the analysis (n = 4). Of the remaining 895 patients, 122 had an obstetric outcome (normal or emergent delivery, abruption, fetal death, and so forth) during the same trauma admission, and 773 were discharged from the hospital with a viable fetus and constituted the study population. The ISS was used to measure the presence and severity of maternal injuries. Study patients were classified into 2 groups; those who were observed but were found to have no injuries (ISS = 0, noninjured, n = 622), and those patients who had identified injuries (ISS ≥ 1, injured, n = 151).

Outcomes of interest for this analysis were PTD and LBW. Although these 2 variables normally are correlated highly, only 54% of the deliveries were concordant (both PTD and LBW), while the remaining 46% were either PTD or LBW. The definition of PTD used for this study was delivery before 37 weeks' gestation. To analyze only those with potential for this outcome, all PTD calculations were limited to pregnant patients with a trauma admission earlier than 37 weeks' gestation (n = 654). LBW was defined as birth weight less than 2,500 g, and the total study population (n = 773) was used for all LBW calculations (Fig. 1).

Three separate analyses were performed. First, the incidence of PTD and LBW, and respective relative risks, were determined for injured patients, using noninjured controls as

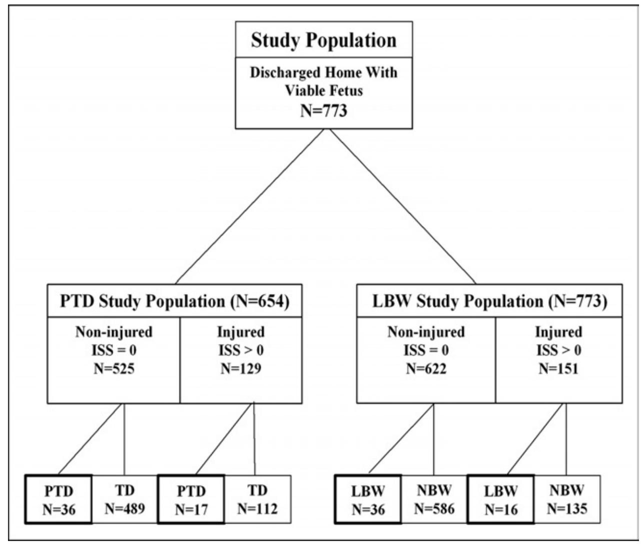

Fig. 1. Flow diagram for study population. TD = term delivery, NBW = normal birth weight.

the referent group. To quantify the public health impact of the delayed effect of trauma on pregnancy, the attributable risk percentage (AR%) and the population attributable risk percentage (PAR%) for these 2 outcomes were determined. These statistics estimate the percent reduction, in the risk of PTD and LBW, that would occur if injuries during pregnancy were prevented, for both pregnant trauma patients and for the pregnant population overall. Second, multivariate logistic regression analysis was performed to determine independent trauma-related risk factors for PTD and LBW, while controlling for other known risk factors including maternal age, race, nulliparity, body mass index, and smoking history. Trauma-related risk factors entered into regression models were ISS, trauma mechanism (motor vehicle collision, assault, fall vs. penetrating), presence or absence of any abdominal injury, GA at trauma event (wk), and emergency department systolic blood pressure (in mm Hg). Separate models were created for PTD and LBW as the dependent variable, and their relationship with trauma-related risk factors was measured as odds ratios with 95% confidence intervals. Both the PTD and LBW models provided a good fit for the data (Hosmer-Lemeshow goodness-of-fit chi square of 8.97, P = .345; and 7.69, P = .464, respectively). Finally, based on independent risk factors determined from multivariate analysis, patients were stratified further by ISS (ISS 1–4 vs. > 4) and by GA at trauma event (>24 wk vs. earlier in gestation), and the incidence of PTD and LBWD, and respective relative risks were determined for each subgroup.

The study was approved by the institutional review board. Data are summarized as mean ± SD, median and interquartile range, or percentage. The Student t test and Mann-Whitney statistical tests were used for continuous variables, and the chi-square and Fisher exact test for categoric variables. A P value of less than .05 was considered statistically significant for all tests. SPSS 13 for windows (SPSS Inc., Chicago, IL) was used for all statistical analyses.

Table 1
Baseline demographics and trauma-related factors for comparison groups

	Noninjured (ISS = 0, n = 622)	Injured (ISS ≥ 1, n = 151)	*P* value
Age, y	23 ± 5	24 ± 6	.04
Race			.15
White	35%	27%	
Black	5%	9%	
Hispanic	58%	61%	
Other	2%	3%	
Nullaparity	40%	31%	.05
Maternal body mass index, kg/m^2	32 ± 7	31 ± 8	.09
Smoking history (% reported current smokers)	1.0%	2.6%	.10
Mechanism			<.01
Fall	45%	46%	
MVC	42%	25%	
Assault	8%	23%	
% Penetrating injury	0%	5%	<.01
Seatbelt use (%-MVC only)	81%	73%	.24
Median GA at time of trauma, wk (interquartile range)	31 (27–35)	30 (27–35)	.19
Emergency department GCS	15.0 ± 0.0	14.9 ± .2	.32
Emergency department systolic blood pressure, mm Hg	120 ± 16	120 ± 17	.80
Revised trauma score	12.0 ± .0	11.9 ± .3	.50
% Requiring blood transfusion	0%	.7%	.195

MVC = motor vehicle collision; GCS = Glasgow coma scale.

Results

Baseline demographics and trauma-related risk factors are described for the injured and the noninjured groups in Table 1. The 2 groups are clinically similar, except for noninjured patients being somewhat younger and a higher percentage of noninjured patients being nulliparous. There was a higher proportion of motor vehicle crashes in the noninjured group, and a higher proportion of assault in the injured cohort. All penetrating injuries (n = 8) were noted in the injured group only.

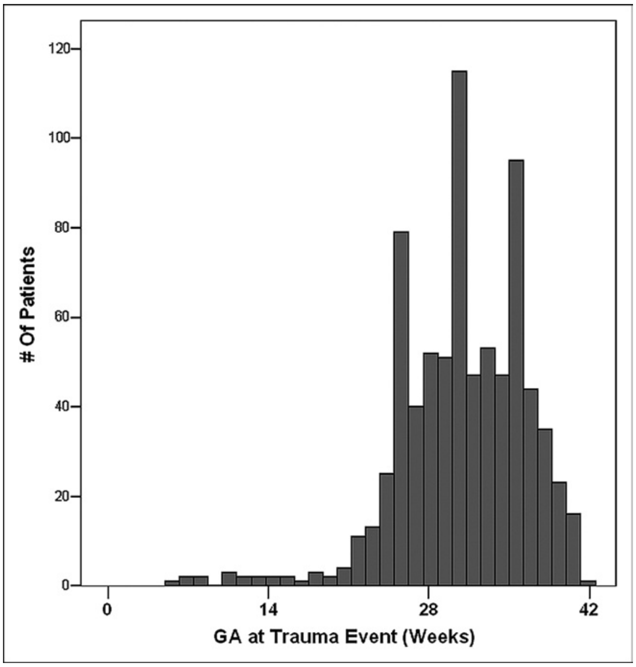

Fig. 2. Distribution of GA at the trauma event.

Most of the patients sustained trauma during the second and third trimesters of pregnancy (Fig. 2), and the mean time interval from the trauma discharge to the subsequent admission for delivery was almost 2 months (59 ± 39 d). The majority of injured patients sustained mild injuries (Table 2), with a mean ISS of 1.8 ± 2.3 (range, 1–22). Most of the patients sustained minor skin and soft-tissue injuries (71.5%). The remaining injuries included head/neck (19.2%), chest (3.3%), abdomen (5.3%), and extremities (4.6%). The mean hospital stay was 1.4 ± 3 days, and greater than 92% of admissions were for 24-hour observation. All injured patients presented as normotensive (systolic blood pressure > 90 mm Hg) and only a single injured patient required intensive care unit admission. Four patients were taken from the emergency department directly to the operating room: 2 for exploratory laparotomy, 1 for an open tibia/fibula fracture, and 1 for placement of a thoracic epidural for multiple rib fractures. All 4 patients were discharged home with a viable fetus with only 1 pregnancy resulting in subsequent PTD and associated LBW.

Maternal injury had a significant effect on pregnancy outcome after trauma center discharge. The risk of PTD throughout the remainder of the pregnancy was almost

Table 2
Distribution of ISS

ISS	Frequency (%)
0	622 (80.5)
1	123 (15.9)
2	1 (.1)
4	21 (2.7)
5	1 (.1)
9	4 (.5)
22	1 (.1)

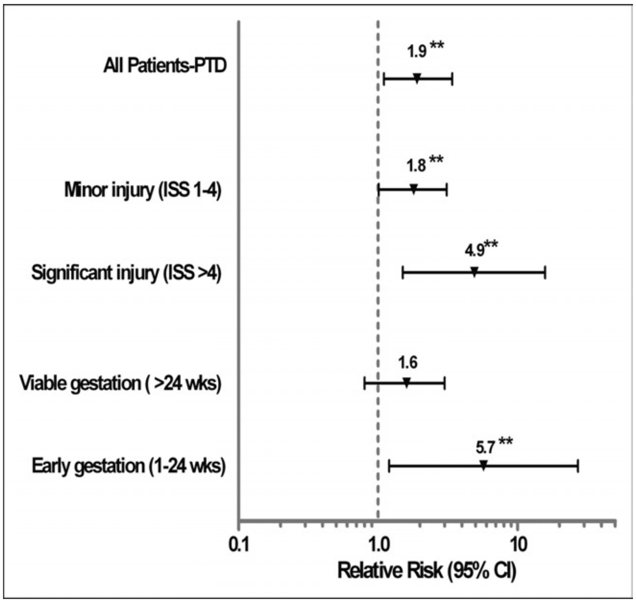

Fig. 3. Relative risks for PTD and subgroups (injured vs. noninjured). **Statistically significant, x-axis (log scale).

2-fold higher for injured patients compared with noninjured patients (13.2% vs. 6.9%; relative risk, 1.9; 95% confidence interval, 1.1–3.3; P = .018; Fig. 3). Similarly, the risk of LBW also was increased significantly (10.6% vs. 5.8%; relative risk, 1.8; 95% confidence interval, 1.04–3.2; P = .034; Fig. 4). The AR% and PAR% for PTD (47% and 15%) and for LBW (45% and 14%) confirms the major public health impact these findings represent.

Multivariate logistic regression revealed that after adjustment for age, race, nulliparity, maternal body mass index, and smoking history, ISS was a significant risk factor for PTD, whereas GA at the trauma event was significant for LBW (Table 3). For every single point increase in ISS, the odds of PTD increased by 36%. For every week earlier in gestation the trauma event occurred, the odds of LBW increased by 6%.

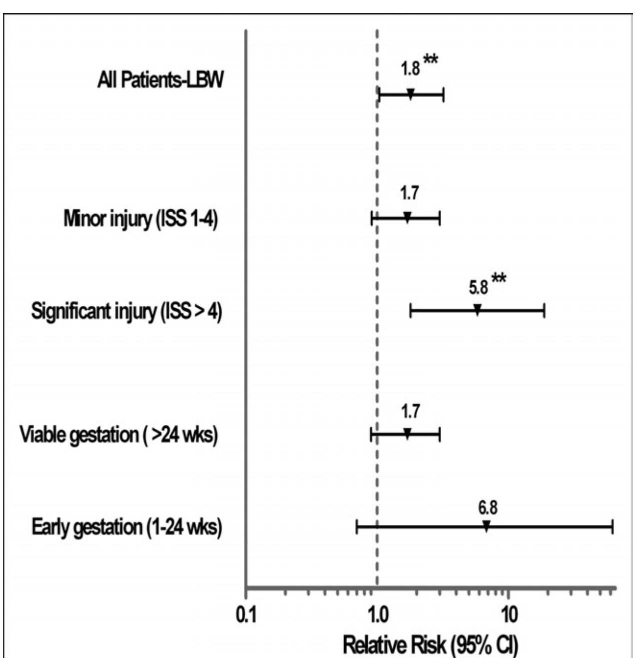

Fig. 4. Relative risks for LBW and subgroups (injured vs. noninjured). **Statistically significant, x-axis (log scale).

Table 3
Multivariate logistic regression indicating independent trauma risk factors associated with PTD and LBW

	Odds ratio (95% confidence interval)	P value
Preterm delivery (n = 654)		
ISS	1.36 (1.02–1.80)	.037†
GA at trauma, wk	.96 (.90–1.02)	.212
Abdominal injury, yes/no	4.78 (.74–30.6)	.100
Mechanism of injury*		
MVC	.56 (.27–1.16)	.122
Assault	.47 (.13–1.68)	.244
Penetrating	.32 (.01–8.40)	.491
Emergency department systolic blood pressure, mm Hg	1.01 (.99–1.03)	.255
Low birth weight (n = 773)		
ISS	1.17 (.90–1.53)	.232
GA at trauma, wk	.94 (.89–.99)	.031†
Abdominal injury (yes/no)	2.12 (.24–18.3)	.494
Mechanism of injury*		
MVC	.53 (.25–1.11)	.094
Assault	.62 (.20–1.92)	.405
Penetrating	.71 (.03–16.1)	.829
Emergency department systolic blood pressure, mm Hg	1.00 (.98–1.03)	.713

* Reference: fall mechanism (most common).

† Statistically significant. In addition to the variables listed in the table, the following covariates were included in the model: age, maternal BMI, maternal race (white, black, hispanic vs others), smoking history, and nulliparity, none of which were statistically significant.

Patients were stratified further by ISS and GA at the trauma event. ISS was divided into those with minor injury (ISS = 1–4), and those with significant injury (ISS > 4). GA at the trauma event was stratified into those patients with a trauma occurrence after 24 weeks' gestation (threshold of fetal viability), and those with trauma that occurred earlier in gestation (GA 1–24 wk). Compared with noninjured patients, the risk of PTD during the remainder of the pregnancy was significantly higher in patients with both minor injuries and significant injuries (Fig. 3). Similarly, the risk of PTD was higher for those with injuries after 24 weeks; gestation, and in those in whom injuries occurred earlier in gestation, but reached significance only in the early gestation subgroup. Although LBW followed a similar trend with a higher risk of those injured in all subgroups, only those with significant injury reached statistical significance (Fig. 4).

Conclusions

This study shows that trauma during pregnancy resulting even in minor injury, significantly increases the risk of PTD and LBW throughout the remainder of gestation. This risk remains increased despite normal fetal monitoring and obstetric evaluation before discharge. Patients with increasing severity of injuries, and those who are injured before 24 weeks' gestation, are at even higher risk for fetal complications. Current algorithms for fetal monitoring after trauma have been shown to identify pregnant patients who can be discharged safely from the hospital [7,8]. Our findings suggest that such patients should continue to be considered high-risk obstetric patients for the remainder of their pregnancy.

In a study of 476 pregnant women by Connolly et al [11], no adverse outcomes related to trauma subsequently occurred when fetal monitoring was normal and symptoms of vaginal bleeding, uterine contractions, or uterine tenderness were absent. In contrast, El-Kady et al [13] showed that those with a history of trauma prenatally had increased risk of placental abruption, preterm labor, and maternal death at delivery, compared with those without a history of trauma during pregnancy. Our findings are consistent with the population study by El-Kady et al [13], whose conclusions were based on a comparison with random pregnant controls without history of trauma admission. Our analysis strengthens those prior conclusions, and gives a more accurate estimation of subsequent risks to the pregnant trauma patient by limiting both the control and study groups to those who required trauma admission.

Two plausible mechanisms may explain our findings. First, trauma may be a marker for lifestyle risks that affect pregnancy outcome. It has been shown that pregnant women involved in motor vehicle crashes are more likely to be younger, unmarried, less educated, more likely to use tobacco and alcohol, and initiate prenatal care later in pregnancy [14]. Similarly, physical abuse during pregnancy has been shown to correlate with tobacco and alcohol use, and victims are twice as likely to delay prenatal care until the third trimester [19–22]. A second plausible mechanism is that trauma causes anatomic injury to the uteroplacental interface. It is known that severe abdominal trauma is associated with acute placental abruption, the leading cause of fetal loss at the time of trauma admission [8]. This is caused by a shearing effect created at the uteroplacental interface, as a result of fundamental differences in tissue characteristics between the uterus and placenta [23]. Less-severe injuries could result in subclinical chronic abruptions, which may be responsible for the delayed outcomes documented in this study [13,24]. We have shown in the current analysis that the risk of subsequent PTD or LBW is higher as ISS increases and for injury early in gestation. It is plausible that as the injury severity increases, the likelihood of subclinical abruption is higher. Similarly, the uteroplacental interface may be more susceptible to injury early in gestation. Also, the frequency of injury may be an important factor. Patients trapped in an environment of abuse or domestic violence may be exposed to repetitive injury. Although we did not have any repeat-trauma admissions in this cohort of pregnant patients, unreported violence or abuse could result in multiple anatomic insults, each adding to an increased risk of complications later in pregnancy. Although the mechanism of injury was not a significant predictor in our regression analysis, it is alarming that there was a significantly higher proportion of assaults among the injured group. In a prospective survey analysis of 16,041 patients by Yost et al [25], pregnant women who reported domestic violence during pregnancy were at significantly increased risk for LBW and neonatal death.

Whether a trauma event is merely a risk factor, or anatomic injury is responsible for the increased risk of PTD or LBW, the most logical and effective way to minimize associated fetal morbidity is through prevention. The AR% and PAR% for both PTD and LBW approached 50% and 15%, respectively, in this study. Assuming a causal relationship with injury during pregnancy as this study proposes, these statistics suggest that the morbidity of PTD and LBW could be halved for those with a history of trauma and reduced by 15% for the pregnant population overall by preventing injuries that occur during pregnancy. These findings underscore prior studies on the incorporation of trauma prevention teaching into routine prenatal care [9,11,13,22].

There were several potential limitations of this study. It was a single-institution experience and may reflect local patient characteristics. As with most retrospective reviews, unmeasured or unknown confounding variables may be responsible for the effects seen, and the subsequent conclusions formulated. More than 100 patients were excluded from the study because of lack of follow-up evaluation. Because the incidence of PTD or LBWD is relatively infrequent, the outcomes of those lost to follow-up evaluation may alter our conclusions. In theory, because we compared injured trauma patients with those involved in a trauma event who escaped injury, the potential for confounding differences in lifestyle risks between the 2 groups should be minimized. It is possible that risk factors for which data were unavailable, such as initiation of prenatal care, socioeconomic factors, or other comorbidities, may be responsible for the conclusions formulated in this analysis. Data concerning alcohol use, acute or chronic, were lacking for the majority of patients, whereas smoking status was limited to self-reported history, which typically is biased because of social taboos on smoking during pregnancy. The accuracy of the AR% and PAR% calculated for this cohort could be biased because of the retrospective nature of the study. In the stratified analysis, some may question the validity of the cut-off point used for those who suffered minimal injury (ISS = 1–4) versus significant injury (ISS > 4). Those with an ISS score of greater than 4 would require at least a single abbreviated injury score of 2 and a concomitant injury, which was considered appropriate for such a minimally injured cohort of patients. Similarly, in regard to stratification by GA at the trauma event, it is known that pregnant patients, particularly those later in gestation, are more likely to present to the hospital after a potentially injurious event because they are pregnant, rather than because they are injured, whereas those with only minor injuries early in gestation may be less likely to present to the trauma center [7]. These potential biases were minimized by including only those patients who presented and were admitted to the trauma center.

In conclusion, this study shows that any injury resulting from trauma during pregnancy is a significant risk factor for delayed complications of PTD and LBW for the duration of the pregnancy. This occurs despite appropriate fetal and maternal evaluation during the trauma admission, with a viable fetus at discharge. Hence, pregnant patients who sustain injuries from trauma should be considered high-risk obstetric patients for the remainder of their pregnancy.

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Discussion

Richard Black, M.D. (Salt Lake City, UT): I would like to congratulate the authors' foresight to look beyond the initial trauma to the mother and unborn child, to the long-term effects of the pregnancy and eventual outcomes. It is unusual and fortuitous that one institution would have so many pregnant trauma victims that could eventually deliver at the same institution and provide continuity and long-term outcome data. Your extensive statistical analyses identified preterm delivery and low birth weight as statistically significant outcomes in the cohort of patients. You state in your conclusion that the injured pregnant women with increased Injury Severity Scores and trauma early in the third trimester are at significant risk for the complications related to preterm delivery and low birth weight infants, thus increasing the morbidity in this group. You and your authors also postulate that there is 2 possible mechanisms in your manuscript that could possibly have led to your findings:

1. That pregnant women involved in motor vehicle accidents are younger, have an increased use of alcohol and tobacco, and are less likely to receive prenatal care.
2. That the trauma to the mother may have affected the blood supply to the placenta, leading to a subclinical abruption, leading to preterm delivery and/or low birth weight infants.

I have 3 questions for the authors:

1. In low birth weight, which is less than 2,500 g, and preterm delivery, which is less than 37 wk, individually and as concordant events are increased risk factors for a poor outcome, but did they lead to increased morbidity in this group of infants (ie, more ICU admissions, more requirements for ventilatory support, or prolonged hospitalization)? If there was a difference, did it make a difference in this group?
2. Was there any correlation with placental pathology specimens that may have suggested subclinical abruption as the cause of early delivery of these small babies, such as clots or scarring, or a small placenta?
3. Since smoking, alcohol, and very little prenatal care can often lead to less favorable outcomes in pregnancy, did your statistical analyses adjust for these potential problems?

Ronald Stewart, M.D. (San Antonio, TX): You need to present this to the OB doctors. I have a comment and a question. The comment is: It is hard for me to imagine that 900 out of 1,000 patients all followed-up at Parkland. You get trauma patients from all over North Texas. What happens to all those suburban moms? I doubt most of them follow-up at Parkland. You broke it up by injury ISS of 1 to 4. This is kind of an unusual grouping to call severe injury ISS greater than 4—I assume you did that because you looked at and found some sort of break point there. What about those patients who would have ISS greater than 9 or ISS greater than 15? Were those numbers just too small to analyze?

Jason Sperry, M.D.: In regards to the ISS cut-point: most patients were very minimally injured. ISS ranged from

0 to 22. There was only 1 patient with 22. The mean ISS score was 1.8 for this minimally injured cohort of patients since they were the ones discharged from the hospital center. We thought that an Injury Severity Score greater than 4 would be an abbreviated injury score of 2 plus a concomitant injury. That was our definition of significant injury. We realize that those injuries were not severe. That cut point was somewhat of a median of the injury severity scores. It was not a fishing expedition, but it was more of a clinical thought early on. In regards to your first comment, we had a follow-up rate of 90% and that is primarily because Parkland is the major institution for the Hispanic population in North Texas. They comprise about 60% of our patients. Parkland is the busiest hospital in the country for obstetric evaluation. That I believe is the reason for such a high rate of follow-up.