Hospital trauma level’s association with outcomes for injured pregnant women and their neonates in Washington state, 1995–2012

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ABSTRACT

Background: Trauma occurs in 8% of all pregnancies. To date, no studies have evaluated the effect of the hospital’s trauma designation level as it relates to birth outcomes for injured pregnant women.

Methods: This population-based, retrospective cohort study evaluated the association between trauma designation levels and injured pregnancy birth outcomes. We linked Washington State Birth and Fetal Death Certificate data and the Washington State Comprehensive Hospital Abstract Recording System. Injury was identified using the International Classification of Diseases, Ninth Revision injury diagnosis and external causation codes. The association was analyzed using logistic regression to estimate odds ratios and 95% confidence intervals (CIs).

Results: We identified 2492 injured pregnant women. Most birth outcomes studied, including placental abruption, induction of labor, premature rupture of membranes, cesarean delivery, maternal death, gestational age <37 weeks, fetal distress, fetal death, neonatal respiratory distress, and neonatal death, showed no association with trauma hospital level designation. Patients at trauma Level 1–2 hospitals had a 43% increased odds of preterm labor (95% CI: 1.15–1.79) and a 66% increased odds of meconium at delivery (95% CI: 1.05–2.61) compared to those treated at Level 3–4 hospitals. Patients with an injury severity score >9, treated at trauma Level 1–2 hospitals, had an aOR of low birth weight, <2500 g, of 2.52 (95% CI: 1.12–5.64).

Conclusions: The majority of birth outcomes for injured patients had no association with hospitalization at a Level 1–2 compared to a Level 3–4 trauma center.

Key Words: Hospital trauma level, injury, injury severity score, maternal, neonatal, pregnancy, trauma system, trauma

INTRODUCTION

Trauma complicates approximately 8% of all pregnancies in the United States[1] and is the leading cause of nonobstetric maternal deaths in the United States.[2,3] In a large, population-based retrospective cohort of pregnant women hospitalized for trauma in California from 1991 to 1999, for every 1000 live births, there were an estimated 2.1 injury-related hospitalizations.[4] The risk of poor maternal and fetal outcomes after injury has been...
well documented. Poor neonatal outcomes have been recorded even after mild traumatic events, to include increased risks of placental abruption, uterine rupture, maternal death, and fetal death. Among pregnant women who sustained severe injuries, a 17-fold increased risk of placental abruption and a 30-fold increased risk of fetal death were reported.

Trauma hospitals are specialized medical centers that offer a range of medical and surgical services specific to the care of injured patients. Level 1 and Level 2 trauma hospitals offer comprehensive trauma services, such as the initiation of definitive care for trauma patients and immediate 24-h coverage by trauma surgeons. Level 3 and Level 4 hospitals have dedicated trauma rooms staffed by emergency medicine physicians but may only have a trauma surgeon on-call and are often located in less populated areas. Many states employ a regionalized approach to trauma care, with designations of both trauma and nontrauma centers. For injured nonpregnant adults treated at large trauma centers in an inclusive trauma system, reduced mortality and improved functional outcomes 1 year after injury were demonstrated in comparison to nontrauma centers. Level 1 trauma hospitals have also been shown to have improved outcomes, even when adjusted for injury severity, compared to lower level trauma hospitals, regardless of the number of patients seen in Level 1 or Level 2 trauma hospitals.

Data from a recent study of injured pregnant women in Washington state support improved maternal and neonatal outcomes associated with trauma hospital care of injured pregnant women compared to nontrauma hospital care. We found no prior studies that examined the influence of treatment at higher trauma level hospitals on the risk of adverse maternal and neonatal outcomes after injury. The aim of our study is to determine if injured pregnant women treated at a Level 1 or Level 2 trauma hospital have improved maternal and neonatal outcomes as compared to those treated at a Level 3 or Level 4 trauma hospital, after adjustment for injury severity and other confounding variables.

 METHODS

We performed a population-based, retrospective cohort study evaluating the association between trauma designation Levels 1 and 2 (Level 1–2) versus Levels 3 and 4 (Level 3–4) and maternal and neonatal outcomes among injured pregnant women admitted to a designated trauma hospital ranging from Level 1 to Level 4. This study did not capture injured pregnant patients who were seen at the emergency department (ED) and subsequently discharged from the ED. The study participants were pregnant women admitted and hospitalized due to injury identified by linking Washington State Birth and Fetal Death Certificate data, Washington state death records, and the Washington State Comprehensive Hospital Abstract Recording System (CHARS). To determine that the injury occurred during pregnancy, we calculated the time difference between the gestational age at delivery and the gestational age at injury hospitalization. Women who were injured and had a spontaneous abortion before 20 weeks gestation were excluded from this study as a birth or fetal death certificate was not issued. Injury was identified using the International Classification of Diseases, Ninth Revision (ICD-9) diagnosis codes 800–999.99 or an external causation code (E code) included with diagnosis codes in CHARS. To focus on injury caused by kinetic forces, we excluded ICD-9 and E code diagnoses of late effects of trauma (905–909, E929), trauma complications (958), poisonings/medicinal toxicity (960–989), medical/surgical complications (996–999), accidental poisonings (E850–E869), medical/surgical misadventures (E870–E879), late effects of injuries (E929), and adverse effects of therapeutic interventions (E930–E949). Since Washington state initiated its trauma hospital designation system in 1995, our study evaluated injured pregnant women who were hospitalized from 1995 to 2012. To better represent trauma care received, the 81 injured pregnant women who had been transferred to or from another hospital after their index injury were excluded from this study. These data, part of a study data set approved by the Washington State Institutional Review Board (IRB), contained neither personal information, protected health information, nor hospital identifiers and were determined to be exempt from review by the Washington state IRB. This manuscript adheres to the applicable EQUATOR Network’s STROBE guidelines for this cohort study.

The two exposure groups were pregnant women hospitalized following an injury in a Level 1–2 trauma center and those hospitalized in a Level 3–4 trauma center, using the Washington State Department of Health trauma hospital designation criteria. Since Washington state had only one Level 1 trauma center, Level 1 and Level 2 trauma centers were combined (n = 7) the dataset to de-identify care provided by an individual hospital. Levels 3 and 4 combined (n = 60) are both resourced to provide initial resuscitation and stabilization but have fewer resources than the larger Level 1 and Level 2 trauma centers.

Patients treated at Level 5 hospitals were excluded in this analysis because hospitals with this trauma level designation stabilize trauma patients for transfer to higher level trauma hospitals in the state. Data regarding specific types of injuries sustained, including fractures/dislocations/sprains/strains (800–849), intracranial injuries (850–854), internal injuries to thorax (860–862), internal injuries of the
abdomen (863–866, 868), internal injuries of the pelvis (867), open wounds (870–897), injury to blood vessels (900–904), superficial injuries/contusions/crushing injuries (910–929), and nerve and spinal cord injuries (950–957) were identified with ICD codes obtained from the CHARS records. We assessed the mechanism of each individual’s injury using E codes including motor vehicle accidents (E810–E829, E846–848), falls (E880–E888), struck accidentally by object, person, or in-between objects (E916–918), accidents by machinery or tools (E919–E920), firearms (E922), overexertion and self-inflicted injury (E950–E959), assaults (E960–E969), and other injuries including nonspecified injuries (E830–E845, E849, E923–E926, E928, E980–E989). We also calculated the injury severity score (ISS) using ICD-9 codes for each individual entered into the ICD-MAP-90 software program (Tri-Analytics Inc., Bel Air, MD). [14]

We identified the maternal and neonatal outcome data as recorded on the birth certificate, fetal death certificate, Washington death records, and maternal and neonatal ICD-9 diagnosis and procedure codes for the hospitalization that resulted in delivery. The maternal outcomes collected included placental abruption (listed on the birth or fetal death certificate or ICD-9 diagnosis code 641.2), preterm labor at <37 weeks gestation (determined by the use of tocolysis on the birth or fetal death certificate or ICD-9 diagnosis code 644.0 or 644.2), cesarean delivery (listed on the birth or fetal death certificate or ICD-9 procedure codes 74–74.2), induction of labor (listed on the birth or fetal death certificate or ICD-9 procedure code 734 or 7301), and premature rupture of membranes defined as rupture more than 24 h before labor onset (ICD-9 procedure code 658.2). The Washington state death records were linked to the study dataset to determine maternal death. A maternal death in this study would include a severely injured pregnant woman at >20 weeks gestation who initially survived the injury, was admitted to a trauma hospital, and then died during the injury hospitalization.

We collected data for neonatal birth outcomes that included premature birth (defined as gestational age <37 weeks recorded on the birth or fetal death certificate), low birth weight (birth weight <2500 g recorded on the birth certificate), presence of meconium at delivery, sign of possible fetal stress (recorded on the birth or fetal death certificate or ICD-9 diagnosis code 763.84), fetal distress (ICD-9 diagnosis codes 768.2, 768.3, or 768.4), fetal death (fetal death at >20 weeks gestation, recorded on the fetal death certificate), neonatal death (a death recorded on the death certificate within 28 days of delivery), or neonatal respiratory distress syndrome (recorded on the birth or fetal death certificate or as ICD-9 diagnosis code 769).

**Statistical analysis**

We compared demographic, obstetric, and injury characteristics of women at Level 1–2 and Level 3–4 trauma hospitals. The demographic characteristics of the injured pregnant women included maternal age (<20 years, 20–34 years, >34 years), race (White, Black, Hispanic, Asian, American Indian, unknown/other), years of education (<12 years, 13–15 years, ≥16 years), marital status (single/divorced, married), median family census tract income (<$25,000/year, $25,000–$55,000/year, >$55,000/year), and insurance (Medicaid/Medicare, self-pay/charity, commercial/health maintenance organization, service contractor, other) (Table 1). The obstetric characteristics included prenatal smoking (yes, no), parity (1, 2, ≥3), gestational age at injury (0–19, 20–27, 28–32, 33–36, 37–43 weeks), gestational age at delivery (20–27, 28–32, 33–36, 37–43 weeks), Kotelchuck adequacy of prenatal care index (inadequate, intermediate, adequate, adequate plus), [15] and ISS (0, 1–8, 9–15, ≥16) (Table 1). [14,16,17]

The types and mechanisms of injury were compared for Level 1–2 and Level 3–4 trauma hospitals using counts and proportions. To describe the proportion of injury types and injury mechanisms among injured pregnant women, we restricted the number of women who had recorded ICD injury codes and women with E codes for mechanisms for Tables 2 and 3, respectively. Not all injured pregnant women who were hospitalized had an ICD injury recorded or an E code mechanism of injury recorded. We also described the number of women who had more than one recorded injury.

We analyzed the association of adverse maternal and neonatal morbidity outcomes by level of trauma hospital with logistic regression to estimate odds ratios and 95% confidence intervals (CIs), building a separate model for each maternal and neonatal outcome. We evaluated for confounding based on confounders reported in prior literature and directed acyclic graphs of pregnancy and trauma, [17,18] including maternal age, years of education, income level, Kotelchuck Index, prenatal smoking, and gestational age at birth. [14,15,19] All outcomes were adjusted for ISS a priori as adjusted in prior literature, [5] and other variables were adjusted for confounders if the model resulted in a >10% change in estimate between the crude and adjusted odds ratios for each exposure and outcome relationship. [20] We also performed a subanalysis of patients with moderate to severe injury indicated by an ISS ≥9 to measure the effect of treatment at Level 1–2 or Level 3–4 trauma hospitals, on birth outcomes.

**RESULTS**

Characteristics of women who were treated at a trauma Level 1–2 hospitals (n = 675) were similar to those who were treated at trauma Level 3–4 hospitals (n = 1817) with respect to age, education, marital status, median
family income, type of insurance, smoking, gestational age at delivery, parity, and adequacy of prenatal care index [Table 1]. A greater proportion of women treated at trauma Level 1–2 hospitals were Blacks (10.3% vs. 3.8%) and had moderate to severe injury (ISS >9) (28.7% vs. 18.6%) compared to women treated at trauma Level 3–4 hospitals. In addition, a greater proportion of neonates were <20 weeks gestation at time of injury among women treated at Level 1–2 hospitals [Table 1].

Among the 541 injured pregnant women with recorded ICD-9 injury diagnoses treated at trauma Level 1–2 hospitals, 80.0% women (n = 433) had one recorded injury, 14.6% women (n = 79) had two injuries. 4.1% women (n = 22) had three injuries, and 1.3% of women (n = 7) had four or more injuries at the time of hospitalization. Among the 1247 injured women with recorded injuries treated at trauma Level 3–4 hospitals, 86.1% women (n = 1074) had one recorded injury, 10.7% of women (n = 134) had two injuries, 2.7% of women (n = 34) had three types of injuries, and 0.4% of women (n = 5) had four or more types of injuries. The two most common types of injuries at trauma Level 1–2 hospitals and trauma Level 3–4 hospitals were fractures, dislocations, and sprains (54.7% and 49.8%, respectively) and superficial, contusion, and crush injuries (30.9% and 30.7%, respectively) [Table 2]. Open wound injuries accounted for 12.6% of trauma Level 1–2 hospital injury diagnoses and 10.7% of trauma Level 3–4 hospital injury diagnoses.

The leading two injury mechanisms, and relevant to public health, among pregnant women at Levels 1–2 were motor vehicle crashes (42.6%) and falls (24.6%), [Table 3]. For Levels 3–4, 32.5% of injury mechanisms were motor vehicle crashes and 36.8% were falls. Overexertion and strenuous movements, to include muscle, ligament, and back strains and sprains, accounted for 10.4% of injury mechanisms in patients at Levels 1–2 and 7.9% among women at Levels 3–4 [Table 3].

No association was noted between the treatment at a Level 1–2 trauma center and odds of either the maternal outcomes of placental abruption, cesarean delivery, induction of labor, premature rupture of membranes, and maternal death, or for the neonatal outcomes of preterm birth, low birth weight, fetal distress, fetal death, neonatal death, or neonatal respiratory distress [Table 4]. Pregnant women treated at trauma Level 1–2 hospitals had a 43% (95% CI: 1.15–1.79) increased odds of preterm labor and their neonates treated at trauma Level 1–2 hospitals had a 66% (95% CI: 1.05–2.61) increased odds of meconium at delivery compared to women and neonates treated at trauma Level 3–4 hospitals [Table 4]. Neonates of the women with moderate to severe injuries (ISS > 9), treated at trauma Level 1–2 hospitals, had a 2.52 increased odds ratio (95% CI: 1.12–5.64) of low birth weight, <2500 g, compared to Level 3–4 hospitals [Table 5].

**DISCUSSION**

We found the most common types of injuries among injured pregnant women at both Level 1–2 and Level 3–4

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**Table 1: Demographic, obstetric, and injury characteristics among injured pregnant women treated at trauma centers in Washington state 1995–2012**

| Demographic characteristics | Trauma level | 1 and 2 (n = 675), n (%) | 3 and 4 (n = 1817), n (%) |
|----------------------------|--------------|-------------------------|-------------------------|
| Age (years)                |              |                         |                         |
| < 20                       | 98 (14.5)    | 219 (12.0)              |
| 20–29                      | 384 (56.9)   | 1064 (58.6)             |
| 30–34                      | 117 (17.3)   | 354 (19.5)              |
| 35+                        | 76 (11.3)    | 180 (9.9)               |
| Race/ethnicity             |              |                         |                         |
| White                      | 480 (72.7)   | 1308 (73.5)             |
| Black                      | 68 (10.3)    | 67 (3.8)                |
| American Indian            | 27 (4.1)     | 91 (5.1)                |
| Asian                      | 46 (7.0)     | 83 (4.7)                |
| Hispanic White             | 39 (5.9)     | 230 (12.9)              |
| Education (years)          |              |                         |                         |
| < 12                       | 341 (53.1)   | 957 (54.2)              |
| 13–15                      | 204 (31.8)   | 532 (30.1)              |
| > 16                       | 97 (15.1)    | 277 (15.7)              |
| Marital status             |              |                         |                         |
| Single                     | 328 (48.6)   | 846 (46.6)              |
| Median family census income|              |                         |                         |
| < $25,000                  | 39 (6.6)     | 114 (7.5)               |
| $25,000–$55,000            | 469 (79.8)   | 1085 (71.3)             |
| > $55,000                  | 80 (13.6)    | 322 (21.2)              |
| Insurance                  |              |                         |                         |
| Medicaid/Medicare          | 353 (52.3)   | 863 (47.5)              |
| Self/charity               | 7 (1.0)      | 33 (1.8)                |
| Commercial/HMO             | 184 (27.3)   | 610 (33.6)              |
| Service contractor         | 116 (17.2)   | 273 (15.0)              |
| Other                      | 15 (2.2)     | 35 (1.9)                |
| Obstetric variables        |              |                         |                         |
| Prenatal smoking           |              |                         |                         |
| Yes                        | 112 (17.1)   | 297 (16.6)              |
| Parity                     |              |                         |                         |
| 1                          | 288 (44.7)   | 694 (38.6)              |
| 2                          | 170 (26.4)   | 571 (31.7)              |
| > 3                        | 186 (28.9)   | 534 (29.7)              |
| Kotelchuck Prenatal Care Index |          |                         |                         |
| Inadequate                 | 86 (14.8)    | 235 (14.9)              |
| Intermediate               | 122 (21.0)   | 295 (18.7)              |
| Adequate                   | 243 (41.8)   | 636 (40.3)              |
| Adequate plus              | 130 (22.4)   | 413 (26.1)              |
| Injury variables           |              |                         |                         |
| Gestational age at injury (weeks) |          |                         |                         |
| 0–19                       | 135 (20.2)   | 210 (11.6)              |
| 20–27                      | 102 (15.2)   | 360 (19.9)              |
| 28–32                      | 123 (18.4)   | 350 (19.3)              |
| 33–36                      | 126 (18.9)   | 368 (20.3)              |
| 37–43                      | 182 (27.3)   | 522 (28.9)              |
| Gestational age at delivery (weeks) |         |                         |                         |
| 20–27                      | 13 (2.0)     | 18 (1.0)                |
| 28–32                      | 17 (2.5)     | 46 (2.5)                |
| 33–36                      | 124 (18.6)   | 293 (16.2)              |
| 37–43                      | 514 (76.9)   | 1453 (80.3)             |
| ISS                        |              |                         |                         |
| 0                          | 96 (15.9)    | 456 (27.5)              |
| 1–8                        | 335 (55.4)   | 896 (53.9)              |
| 9–15                       | 157 (25.9)   | 295 (17.8)              |
| > 16                       | 17 (2.8)     | 14 (0.8)                |

ISS: Injury Severity Score, HMO: Health Maintenance Organization
hospitals included fractures, dislocations, and sprains as well as superficial, contusion, and crush injuries. The most common mechanisms of injury were motor vehicle accidents and falls. Our data show that hospitalization in a Level 1–2 compared to a Level 3–4 trauma center was associated with moderate to severe injuries, ISS > 9, treated at Level 1–2 compared to Level 3–4.

The types and mechanisms of injuries among pregnant women in our study were similar to those of injured pregnant women in prior studies.[23] We found that fractures, dislocations, sprains, and strains were the most common type of injury among patients treated at both a

Table 2: Type of injury among pregnant women treated at trauma centers in Washington state 1995-2012

| ICD-9-CM injury classification | Trauma level | 1 and 2 (n=541), n (%) | 3 and 4 (n=1247), n (%) |
|--------------------------------|--------------|------------------------|------------------------|
| Fractures, dislocations, sprains (800-848) | 296 (56.7) | 621 (49.8) |
| Intracranial injury excluding skull fractures (850-854) | 27 (4.8) | 41 (3.3) |
| Internal injury of intrathoracic organs (860-862) | 14 (2.6) | 13 (1.0) |
| Internal injury of abdominmal organs (863-866, 868) | 26 (4.8) | 21 (1.7) |
| Internal injury of pelvic organs (868) | 5 (0.9) | 17 (1.4) |
| Open wound (870-879) | 86 (15.6) | 134 (10.7) |
| Blood vessel injury (900-904) | 16 (2.9) | 18 (1.4) |
| Superficial, contusion, crushing (910-929) | 167 (30.8) | 383 (30.7) |
| Effects of foreign body entering orifice (930-939) | 2 (0.4) | 3 (0.2) |
| Nerve or spinal cord injury (950-957) | 22 (4.1) | 38 (3.0) |
| Other injuries not specified (959) | 45 (8.3) | 176 (14.1) |

*The sum of percentages for recorded ICD-9 injury classification is >100% because some women had more than one type of injury, †The n is the total number of women which includes only those that had a recorded ICD-9 injury classification.

Table 3: Mechanisms of injury among pregnant women admitted to trauma centers in Washington state 1995-2012

| External cause of injury | Trauma level | 1 and 2 (n=627), n (%) | 3 and 4 (n=1658), n (%) |
|-------------------------|--------------|------------------------|------------------------|
| Motor vehicle accidents E810-E829, E846-E848 | 267 (42.6) | 539 (32.5) |
| Falls E880-E888 | 154 (24.6) | 610 (36.8) |
| Struck accidentally by object or person E916-E918 | 12 (1.9) | 68 (4.1) |
| Accidents by machinery or tools E919-E920 | 12 (1.9) | 21 (1.3) |
| Firearms E922 | 2 (0.3) | 2 (0.1) |
| Overexertion and strenuous movements E927 | 65 (10.3) | 131 (7.9) |
| Suicide attempts, self-inflicted injury E950-E959 | 8 (1.3) | 6 (0.4) |
| Assault, purposely inflicted injury E960-E969 | 43 (6.9) | 68 (4.1) |
| Other E830-E845, E849, E923-E926, E928, E980-E989 | 64 (10.2) | 213 (12.8) |

*The total number of women includes only those who had an external cause of injury reported in the hospitalization data.

Table 4: Maternal and neonatal outcomes among injured pregnant women admitted to trauma hospitals in Washington state

| Outcomes | Trauma level | 1 and 2 (n=675), n (%) | 3 and 4 (n=1817), n (%) | Adjusted OR (95% CI) |
|----------|--------------|------------------------|------------------------|---------------------|
| Maternal | Placental abruption | 37 (5.5) | 84 (4.7) | 1.00 (0.64-1.56)* |
| | Preterm labor | 172 (25.5) | 376 (20.7) | 1.43 (1.15-1.79)* |
| | Induction of labor | 185 (27.4) | 529 (29.1) | 0.97 (0.79-1.20)* |
| | Premature rupture of membranes | 35 (5.2) | 87 (4.8) | 0.98 (0.61-1.66)* |
| | Cesarean delivery | 188 (27.9) | 569 (31.3) | 0.86 (0.70-1.06)* |
| | Maternal death | 5 (0.7) | 10 (0.6) | 1.14 (0.34-3.87)* |
| Neonatal | Gestational age <37 weeks | 93 (13.8) | 207 (11.4) | 1.23 (0.93-1.62)* |
| | Low birth weight <2500 grams | 64 (9.5) | 147 (8.1) | 1.24 (0.901.72)* |
| | Meconium at delivery | 45 (6.7) | 78 (4.3) | 1.66 (1.05-2.61)* |
| | Fetal distress | 38 (5.6) | 100 (5.5) | 0.93 (0.61-1.40)* |
| | Fetal death | 12 (1.8) | 17 (0.9) | 1.47 (0.64-3.36)* |
| | Neonatal respiratory distress | 17 (2.5) | 35 (1.9) | 1.28 (0.56-2.92)* |
| | Neonatal death | 9 (1.3) | 18 (1.0) | 1.09 (0.45-2.68)* |

*Adjusted for ISS, education, †Adjusted for ISS, ‡Adjusted for ISS, income, †Adjusted for ISS, income, Kotelchuck index. ISS: Injury Severity Score, OR: Odds ratio, CI: Confidence interval.
Level 1–2 and a Level 3–4 trauma-designated hospitals. The second most common type of injury among both of our patient groups were superficial injuries, contusions, and crushing injuries. These two types of injuries were also the two most common ones found in a larger population-based retrospective study of 10,316 deliveries of women who sustained injuries in California. While many of the injuries among pregnant women in our study were more minor, indicated by an ISS < 9, the current ISS system does not include ICD codes for injury to the gravid uterus or injury to the in utero fetus since the ISS was developed in exclusively in a nonpregnant population. This may be one of the reasons an injured pregnant woman would have been admitted to the hospital, even with a minor corresponding ISS score ranging from 0 to 8.

Similar proportions of injury mechanisms among pregnant women recorded in our study were also reported in an epidemiologic study of pregnancy-associated ED injury visits in Utah. A population-based retrospective cohort study of 7350 injured pregnant women who were evaluated in an ED noted the two most common mechanisms of injury among injured pregnant women were motor vehicle crashes (28.7%) and falls (14.6%). A population-based retrospective cohort study of 3429 injured pregnant women hospitalized in either a trauma or nontrauma designated hospital, which analyzed maternal and fetal outcomes in trauma during pregnancy, also reported motor vehicle crashes (48%) and falls (25%) as the two leading mechanisms of injury for pregnant women. These descriptive data are important for public health efforts focused on education and targeted injury prevention programs for this vulnerable population.

Among injured pregnant women who were hospitalized in either a Level 1–2 or a Level 3–4 trauma hospital, we found a higher odds of preterm labor and meconium at birth among injured women treated at trauma Level 1–2 hospitals compared to those treated at a Level 3–4 hospital. We found no prior literature that evaluated maternal and neonatal outcomes among injured pregnant women who were admitted at different hospital trauma levels. The greater odds of preterm labor at higher level trauma hospitals may be explained by the fact that many of these hospitals are also higher level perinatal care centers. Injured pregnant women experiencing preterm labor may more likely be transported to a hospital with a neonatal intensive care unit and capabilities to provide advanced care for premature infants in the event delivery occurs. The increased odds of preterm labor and meconium at birth among the pregnant patients treated at Level 1–2 trauma hospitals may also be explained by uterine or placental injury. The ISS does not include uterine or placental injury as part of the scoring system and this may have resulted in more severely injured pregnant women at Level 1–2 trauma hospitals, resulting in residual confounding by injury severity as another possible explanation of our findings.

Among the moderate to severely injured patients, ISS ≥9, more neonates of women treated at Level 1–2 hospitals had low birth weight. While the gestational age at delivery between Level 1–2 and Level 3–4 hospitals was similar, the gestational age at injury was younger among those treated at Level 1–2 than Level 3–4 hospitals. It is possible that severe injury early in pregnancy affects early fetal development. Weiss et al. demonstrated in a retrospective cohort study of injured pregnant women that those injured in the first trimester compared to the third trimester had increased risk low birth weight. El-Kady et al. showed that pregnant women who were at the extremes of age (<20 or >35 years) and <28 weeks gestation at the time of a severe injury were at the highest risk of adverse birth outcomes. These findings may be explained by the fetal response to the physiologic stress of trauma early in gestation or by possible subclinical placental injury that...
resulted in placental insufficiency not captured by the ISS[^17] and low birth weight at time of delivery.[^4]

The majority of maternal outcomes including placental abruption, cesarean delivery, induction of labor, premature rupture of membranes, and maternal death, as well as of neonatal outcomes including prematurity, fetal distress, and neonatal respiratory distress, did not differ by level of trauma hospital, indicating no advantage from treatment at a higher level trauma hospitals. Prior studies support the advantage of higher tiered trauma centers among the most severely injured nonpregnant patients with ISS >15 although no prior studies to our knowledge have evaluated trauma center level among injury pregnant women.[^6]-[^10] This lack of advantage with higher level trauma care may be explained by the finding that most of the injured pregnant women in our study had ISS <15 and may have had good outcomes regardless of the level of trauma center to which they were admitted. Higher and lower trauma level hospitals share similarities in treatment protocols, maternal and fetal resuscitation and monitoring, trauma staff training, and surgical and obstetric capabilities. These similarities among all levels of trauma hospitals may contribute to the majority of similar birth outcomes among injured pregnant women.

Our study’s limitations included possible residual confounding by injury severity where more severely injured pregnant women are directed to Level 1–2 trauma centers and less severely injured pregnant women are directed to Level 3–4 trauma centers. We did not have the statistical power, due to small sample sizes, for subgroup analyses of the differences in specific mechanisms and types of injuries with regard to outcomes. Although we adjusted for ISS, it does not completely capture true injury severity in the injured pregnant patient because it does not include uterine and placental injuries in the ISS algorithm.[^17] Our administrative dataset did not have specific information to measure which and how many of the patients were seen by an activated trauma service. Our findings may not be generalized to women with pregnancy loss earlier than 20 weeks of gestation, those who were transferred to a higher level of trauma care, or to injured pregnant women with less severe injuries who may have been evaluated, treated, and discharged home from a clinic or from an ED but did not require hospitalization. Finally, we did not assess patients transferred to higher trauma care level hospitals, a population where a benefit of Level 1–2 compared to Level 3–4 hospitals may have been demonstrated in maternal and neonatal outcomes.

**CONCLUSIONS**

While the level of trauma center care was not associated with most of the maternal and neonatal birth outcomes, we did find increased odds of preterm labor and meconium at birth among injured pregnant women treated at higher level trauma hospitals (Level 1–2) and increased odds of low birth weight among moderate to severely injured pregnant women, ISS >9, treated at higher level trauma hospitals (Level 1–2) compared to Level 3–4. The findings of this retrospective cohort study require confirmation in larger studies in heterogeneous populations. Further research in both exclusive and inclusive trauma systems in different regions of the United States would help better understand the relationship between trauma hospital levels and maternal and neonatal outcomes in injured pregnant women. Future studies that evaluate triage guidelines for injured pregnant patients and treatment protocols, to include the time from injury to care, use of monitoring, treatment methods, or standards of care for pregnant trauma patients treated in a variety of trauma level hospitals from Level 1 to Level 4, would also improve insights into care and outcomes. Future studies that assess long-term maternal and neonatal outcomes could also help inform state trauma systems and improve treatment protocols and practice for treating injured pregnant women and their neonates.

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**Conflicts of interest**

There are no conflicts of interest.

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