Trauma is the leading nonobstetric cause of morbidity and mortality in pregnancy; approximately one out of every 15 pregnancies is complicated by trauma. Motor vehicle accidents are a major cause of trauma during pregnancy. Severe injury occurs in approximately 10% of cases, a situation associated with high likelihood of preterm delivery, placental abruption, cesarean delivery and increased maternal and fetal mortality. Nevertheless, obstetric complications may also occur with less severe injuries. All pregnant trauma patients should be managed according to Advanced Trauma Life Support guidelines. In total, 2–6 h of observation with fetal monitoring are recommended for pregnant trauma patients who are not admitted. Poor maternal and fetal outcome can be predicted by the presence of several risk factors such as ejection from the vehicle, pedestrian or motorcycle injury, lack of seatbelt use, abdominal, pelvic or intracranial injury, loss of consciousness, maternal tachycardia, low Glasgow coma scales, hypotension and abnormal fetal heart rate. Treating the mother correctly is beneficial for the fetus, thus trauma guidelines should be adhered to, despite the need for multidisciplinary efforts and concern for the fetus. Approximately 2% of admitted pregnant trauma patients die; perimortem cesarean delivery should be considered when the fetus is viable (i.e., gestational age >24 weeks) within minutes of maternal death.

Keywords: cesarean delivery • delivery • labor • motor vehicle accidents • pregnancy • trauma

Unintentional injury is the leading cause of death in women aged 15–45 years in the USA. Motor vehicle accidents (MVAs) account for more than half of these deaths [1]. Treatment of the pregnant trauma patient is challenging both professionally and conceptually; maternal physiology differs from that of nonpregnant women of the same age. Aside from the usual trauma injuries, the clinician must keep in mind the potential for obstetrical complications. Clinical attention may be diverted from guideline-directed therapy because treatment is being provided concomitantly to two trauma patients: mother and fetus. Nevertheless, it is requisite that treatment of the mother takes precedence, despite distraction provided by concern for the fetus. As a general rule, good maternal treatment is beneficial for the fetus.

Optimizing fetomaternal treatment requires a multidisciplinary effort. Expert caregivers in maternal–fetal medicine and/or obstetrics, anesthesiology, trauma surgeons and emergency medicine physicians must collaborate without deviating from simple trauma guidelines that prioritize airway support, breathing and circulation [2,3]. Viewing the mother (and not the fetus) as the object of treatment may be exigent.

Most challenging is the realization that an instantaneous decision to salvage only one patient (mother or child) may be required at any given time. Examples include hysterotomy for early nonviable pregnancy with placental abruption (maternal salvage) and perimortem cesarean section (fetal salvage). However, such decisions can only be performed after rough assessment of gestational age based on clinical examination, when fetal viability is established (i.e., 23–24 weeks of gestation).

This article will appraise the recent literature regarding trauma in pregnancy (mostly MVA related) and highlight new data that are relevant to management of the pregnant trauma patient.

Physiology of pregnancy
During normal pregnancy, virtually every organ system undergoes anatomical and functional changes. These changes can affect the normal responses to trauma. The physiologic changes...
most relevant to management of trauma during pregnancy are reviewed in the following section. The implications of these changes to trauma management are described in Table 1.

**Airway, breathing & ventilation**

Increased levels of estrogen cause connective tissue edema in the respiratory tract. Increased oropharyngeal mucosal congestion predisposes the patient to bleeding during intubation. Pharyngolaryngeal and vocal cord edema may hamper the successful passage of a tube. These changes, together with an increased weight, alter the airway during pregnancy, placing the pregnant patient at risk for difficult airway management [4].

The diaphragm rises approximately 4 cm during pregnancy. The subcostal angle widens appreciably as the transverse diameter of the thoracic cage increases. The thoracic circumference increases, but not sufficiently to prevent a reduction in the residual volume of air. The functional residual capacity and the residual volume of air in the lungs are thus decreased [5]. Women in the third trimester of pregnancy have functional residual capacity and expiratory reserve volumes that are 20–30% lower than those of healthy nonpregnant women [6].

Tidal volume, minute ventilation and minute oxygen uptake increase significantly as pregnancy advances. Compared with healthy nonpregnant women, minute ventilation is approximately 30% higher in the first trimester of pregnancy and this does not change appreciably afterwards [6]. Subjective dyspnea appears in the first trimester and continues throughout pregnancy [7]. This physiological dyspnea has been attributed to the effect of progesterone and estrogen on central and peripheral chemoreflex drives to breathe, which leads to increased tidal volume [8]. The main implication of combined decreased reserve volumes and increased minute ventilation is that pregnant women are more vulnerable to the effects of hypoxia and desaturation occurs rapidly.

**Blood volume**

Maternal blood volume increases markedly during pregnancy. At 12 weeks of gestation plasma volume has already expanded by approximately 15% [9]. This increase becomes more marked toward the end of the pregnancy, by which time the blood volume of the pregnant woman averages 40–45% above nonpregnant volumes [10]. The expansion in blood volume results from an increase in both plasma and erythrocytes. Hemoglobin and hematocrit decrease slightly during normal pregnancy, leading to the classic physiological anemia of pregnancy.

**Cardiovascular system**

The cardiovascular changes that occur during pregnancy are comparable to the acute changes observed during moderate to strenuous exercise [11]. During the second half of a normal pregnancy the fraction of maternal cardiac output (CO) distributed to the uterine circulation doubles [12]. Within 5 weeks of gestational age, CO at rest increases by approximately 10% [12–14]. The increase in CO peaks towards the end of the second trimester, with values approximately 30–50% greater than nonpregnant values.

The increase in CO is caused by a marked reduction in afterload due to diminished vascular resistance teamed with increased blood volume and basal metabolic rates. Blood pressure usually

<table>
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<th>Assessment</th>
<th>Physiological change during pregnancy</th>
<th>Effect</th>
<th>Implication</th>
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<tr>
<td>Airway</td>
<td>Increased estrogen levels</td>
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<td>Weight gain</td>
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<td>Increased neck and mammary fat levels</td>
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<td>Breathing</td>
<td>Hormonal effects on central and peripheral breathing chemoreceptors</td>
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<td>Subjective dyspnea and rapid respiratory rate</td>
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<td></td>
<td>Weight gain, elevated diaphragm</td>
<td>Decreased functional residual capacity</td>
<td>Rapid deoxygenation</td>
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<td></td>
<td>Increased metabolism</td>
<td>Increased oxygen consumption</td>
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<tr>
<td>Circulation</td>
<td>Increase in plasma volume and erythrocyte count</td>
<td>Increased blood volume</td>
<td>Physiologic anemia</td>
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<td>Increased concentrations of most clotting factors</td>
<td>Activated state of coagulation cascade</td>
<td>Increased tendency for thrombosis</td>
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<td></td>
<td>Hormonal changes leading to cardiovascular effects simulating exercise</td>
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<td></td>
<td>Effects secondary to uterine growth</td>
<td>Decreased systemic vascular resistance</td>
<td>Lower baseline blood pressures</td>
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<td></td>
<td>Compression of the vena cava</td>
<td>Heart rotation to the left</td>
<td>Left axis deviation on ECG</td>
</tr>
<tr>
<td></td>
<td>Doubled uterine circulation and increased cardiac output</td>
<td>Supine hypotension</td>
<td>Reduced cardiovascular reserve with rapid development of shock</td>
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</table>
In 2002, other major causes of trauma during pregnancy include falls and domestic abuse during pregnancy [19–21]. The authors of this article believe the difference in admission rate is attributable to a combination of cultural, legal (i.e., fear of litigation) and scientific causes (e.g., lack of solid data on risk factors for maternal and fetal morbidity and mortality, risk of a poor outcome even with minor trauma, paucity of evidence-based guidelines) that all lead to an overly cautious approach to the treatment of pregnant women.

Rates of severe injury
The likelihood of sustaining a severe injury is higher with MVAs (31%) and GSWs (50%) in comparison to falls (0%) or assaults (22%) similar to the general population [27,33]. However, most injuries sustained by pregnant trauma patients are not life or limb threatening. Reported rates of severe injury (injury severity scores [ISS] >8) among pregnant trauma patients range between 9.2 and 16.2% [34–37]. Quoted rates may be higher than true rates since most reports come from level 1 trauma centers and include only admitted trauma patients. Even in these reports, 30.2–41.2% of the pregnant trauma patients were uninjured. In a 10-year population-based study in Sweden, an injury level was assigned to each woman based on a police evaluation method. In this study, 1% (15 out of 1721) of the women involved in an MVA sustained fatal injuries, 15% (251 out of 1721) sustained a major injury, 85% (1455 out of 1721) sustained minor injuries and another 549 were not injured [38].

Admission rates
Injuries leading to ambulance transfer and hospital admission of pregnant MVA patients would not have led to transfer or admission in the absence of pregnancy [25,26,39,40]. A recent publication estimated 4.1 admissions for pregnant MVA patients per 1000 deliveries yearly in the USA (~170,000 annual admissions) [22]. Like most papers dealing with this issue, the authors provided no explanation for the high admission rate; in the general population the admission rate is lower – approximately 1.4 per 1000 adults [41]. Cahill et al. suggested that admission for observation after mild trauma during pregnancy is a natural extrapolation of the conservative treatment approach prevalent in the care of pregnant women after life-threatening injuries [39]. The authors of this article believe the difference in admission rate is attributable to a combination of cultural, legal (i.e., fear of litigation) and scientific causes (e.g., lack of solid data on risk factors for maternal and fetal morbidity and mortality, risk of a poor outcome even with minor trauma, paucity of evidence-based guidelines) that all lead to an overly cautious approach to the treatment of pregnant women.

Trauma in pregnancy: causes, incidence & rates of admission
Approximately 5–8% of all pregnancies are complicated by trauma [19–21]. MVAs are the leading cause of maternal injury during pregnancy [19,22–24]. Other major causes of trauma during pregnancy include falls and domestic abuse [22,25]. In 2002, 26% of 16,982 pregnant trauma patients admitted to a sample of US hospitals were involved in a MVA, and the mechanism of injury in an additional 24% was falls [22]. In a population-based study of pregnancy-associated injuries (n = 7350), the leading mechanisms of injury were similar: car occupant during an MVA (22.4%) and falls (17.9%) [26]. This correlates with data collected from 18 level 1 trauma centers and 51 non-trauma center hospitals in 14 US States (n = 15,009) where MVAs were responsible for almost 50% of injuries among the general population [27]. The prevalence of causes of trauma in the general population data from the National Trauma Database (NTD) (n = 627,664) differs somewhat; falls are the most common cause of injury (34.7%), particularly in women, and MVAs are only second in prevalence (31.8%) [201]. The contradiction between sources may stem from exclusion of patients with superficial injury who are not admitted to the hospital in the NTD registry. Penetrating injury is less common during pregnancy; stab and/or gunshot wounds (GSWs) are mostly described [28–30]. In a population-based study (n = 7350) 10% of injuries were incurred by cutting or piercing [26]. Penetrating injury incurred at an early gestational age mostly affects the mother; however, a GSW to the pelvis can injure the fetus as well [31]. As the uterus expands above the pelvis brim, the fetus becomes more vulnerable. The possibility that domestic abuse led to the trauma should never be overlooked. In one study 1% of pregnant women suffered domestic abuse [32].

Acid–base equilibrium
The increased respiratory tidal volume lowers blood carbon dioxide partial pressure slightly, which paradoxically causes dyspnea. To compensate for the resulting respiratory alkalosis, plasma bicarbonate levels decrease from an average of 26 mmol/l to an average of 22 mmol/l. As a result, blood pH is also only minimally increased.

Uterine growth
As pregnancy progresses, the uterus distends over the pelvis brim. The uterus becomes an intra-abdominal organ at 12 weeks of gestation. At 20 weeks, the uterine fundus can be palpated at the maternal umbilicus. By the 36th week of gestation, the uterus reaches the costal margin [18].

The implications for the management of trauma during pregnancy of the changes described in the preceding paragraphs are diverse (Table I) but one must always bear in mind three major issues:

- Hypervolemia and anemia of pregnancy are very common. Both lead to maternal tachycardia. Pathological tachycardia (e.g., secondary to hemorrhage) will be diagnosed too late unless a very high level of clinical suspicion is maintained;
- Anatomical, hormonal and physiological changes will likely make endotracheal intubation difficult;
- Supine hypotension is common; therefore, a left tilt position may be preferable to a fully supine position.

Nadirs at around mid-pregnancy and rises thereafter. Diastolic pressures decrease more than systolic pressures. Resting heart rate increases an average 10 bpm during pregnancy [18].

The ‘supine hypotension syndrome’ is a physiologically normal finding unique to the second half of pregnancy; in the supine position, the enlarged uterus compresses the venous system returning blood from the lower half of the body. This compression results in reduced preload, decreased CO and lower perfusion pressures [16,17].
Traumatic maternal morbidity & mortality

Trauma is the leading nonobstetric cause of morbidity and mortality in pregnancy [42–44]. A 4-year review of medical examiner records described 95 cases of maternal deaths; trauma was the cause in 46.3% of cases [42]. Table 2 details the prevalence of maternal and fetal morbidities after trauma.

Maternal morbidity

Maternal involvement in trauma could result in both pregnancy-unrelated and -related injuries.

Pregnancy-unrelated injuries

The injury profile described in pregnant trauma patients is generally similar to that observed in the general population [201]. The typical injury distribution among the general population includes: extremities (62%), head (32%), face (25%), thorax (20%), spine (17%) and abdomen (12%).

Pregnancy-related injuries

Delivery occurs in 38% of admitted pregnant trauma patients [22]. The typical pregnancy-related morbidity encountered after trauma includes (in decreasing order of frequency): uterine contractions, preterm delivery, unplanned cesarean delivery (CD), preterm premature rupture of membranes, placental abruption and uterine rupture.

Placental abruption

The likelihood of placental abruption is higher after trauma during pregnancy compared with uninjured pregnant women (odds ratio [OR]: 1.33; 95% CI: 1.08–1.65; n = 183,305) [26]. The likelihood of placental abruption is increased with higher ISSs, although it is still prevalent in uninjured or mildly injured pregnant patients as well [33]. A 10-year retrospective cohort study of all pregnant women admitted for injury in Washington State (USA) described placental abruption in 1.4% (170 out of 12,578 individuals) when the woman was not injured, 4.9% (13 out of 266 individuals) with nonsevere injuries and 25% (seven out of 28 individuals) in severely injured women [33]. Other studies with similar methodology demonstrate the same trend. For example, among the pregnant women who were admitted after trauma and delivered during admission throughout a 10-year period in California, placental abruption was diagnosed in 6.8% of those with an ISS less than 9 and in 17.8% of those with an ISS of more than 9 [45].

Acceleration–deceleration mechanisms of injury (e.g., an MVA or a fall) may generate shear forces that can cause placental abruption, even when lacking apparent maternal injury. Placental abruption in pregnant women with any trauma-related emergency department visit has been described in 1.7% (125 out of 7350) of cases [26]. Placental abruption in pregnant women admitted after blunt trauma is more prevalent, ranging from 4.4% (12 out of 271 individuals) to 6.8% (20 out of 294 individuals) [34,37].

Antecedents to placental abruption include maternal complaints of abdominal pain, severe contractions with pain disproportionate to the degree of cervical dilation and/or vaginal bleeding. Physical examination may reveal a tender and rigid uterus. Bleeding may be occult, even when significant. When placental abruption is significant the fetus will be affected; bradycardia, prolonged deceleration and repetitive late decelerations have all been described [46–48]. Appropriate therapy consists of prompt

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<th>Complication</th>
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<tr>
<td>Maternal</td>
<td></td>
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<tr>
<td>Death</td>
<td>Among all trauma cases</td>
<td>0–3.8</td>
<td>[33,34,42,52,53]</td>
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<td></td>
<td>Among severe trauma cases</td>
<td>28</td>
<td>[51]</td>
</tr>
<tr>
<td>Severe injury</td>
<td></td>
<td>9.2–16.2</td>
<td>[31–34]</td>
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<tr>
<td>Cesarean delivery</td>
<td>Among all trauma cases</td>
<td>19.4 vs 16 in control</td>
<td>[25]</td>
</tr>
<tr>
<td></td>
<td>Within hours of trauma occurrence</td>
<td>7.2</td>
<td>[51]</td>
</tr>
<tr>
<td></td>
<td>Among mild trauma cases</td>
<td>18 vs 18.9 in uninjured</td>
<td>[30]</td>
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<tr>
<td></td>
<td>Among severe trauma cases</td>
<td>71 vs 18.9 in control</td>
<td>[30]</td>
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<tr>
<td>Placental abruption</td>
<td></td>
<td>1.7–6.8</td>
<td>[27,34,43]</td>
</tr>
<tr>
<td>Uterine rupture</td>
<td></td>
<td>0.3</td>
<td>[49]</td>
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<tr>
<td>Fetal</td>
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<tr>
<td>Death</td>
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<td>0–25</td>
<td>[25,30,31,51,52]</td>
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<tr>
<td>Preterm delivery within hours of trauma</td>
<td></td>
<td>13.3–14</td>
<td>[33,55]</td>
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<tr>
<td>Preterm delivery following discharge from hospital after trauma</td>
<td></td>
<td>18.4</td>
<td>[55]</td>
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<tr>
<td>Low birth weight</td>
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<td>25</td>
<td>[33]</td>
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delivery in severe cases. Expectant management is possible in selected cases provided maternal hemodynamic condition and fetal wellbeing are closely monitored [48,49].

Uterine rupture & uterine penetration
From 20 weeks onwards the uterus thrusts the abdominal content aside, thus protecting the mother from bowel injury. However, uterine rupture or penetration can cause massive hemorrhage since uterine circulation is significantly increased during pregnancy.

Uterine rupture is an infrequent event that, until recently, was described mostly in case reports [50,51]. However, a population-based study in Sweden demonstrated that uterine rupture is present in 17.5% of fetal and neonatal death cases, and that it occurs primarily in cases with fatal maternal injury [38]. Based on the cases of fetal and neonatal death described in this study (40 out of 2270 cases), the rate of uterine rupture was calculated to be 0.3% in pregnant MVA patients. Uterine rupture typically occurs with rapid deceleration or direct compression injuries. Maternal death may be caused by massive hemorrhage from the ruptured uterus. However, the mechanism of injury in these cases is often severely damaging, so other injuries may also be responsible for maternal death.

Uterine penetration has been described in penetrating trauma. Exploratory laparotomy is recommended in high-speed projectile injuries [28]. Importantly, exploratory laparotomy is not an indication for immediate CD if the fetus is stable, particularly if the fetus is extremely preterm [3]. The decision to deliver should be made for obstetric reasons or if irreparable uterine damage compromises maternal life.

Cesarean delivery
Pregnant trauma patients (n = 7350) are more likely than uninjured pregnant women (n = 183,305) to require CD (19.4 vs 16.0%, respectively; OR: 1.27; 95% CI: 1.19–1.36) [26]. When trauma team activation was indicated for any cause except the presence of pregnancy (28 out of 85 cases; 32%), one in six trauma patients required CD within 24 h of the trauma [52]. Among 441 pregnant trauma patients documented in the registries of nine level 1 trauma centers, there were 32 CDs (7.2%). The average time from hospital arrival to CD was 5.6 h [53].

The likelihood of CD in severely injured pregnant trauma patients is significantly higher than the likelihood of CD in pregnant trauma patients with milder injury or in an uninjured control population (71.4% [20 out of 28] vs 18% [48 out of 266] and 18.9% [2372 out of 12,578]; relative risk: 3.8; 95% CI: 2.1–6.9) [33]. The occurrence of placental abruption is also related to high rates of CD; in one study 75% (eight out of 12) of pregnant trauma patients diagnosed with traumatic placental abruption underwent CD [34].

The number of publications describing the indications for CD in pregnant trauma patients following trauma is limited. However, one study noted that in those trauma patients who underwent CD within 24 h of admission, 71% (five out of seven) of CDs were performed due to nonreassuring fetal heart rates (FHRs) and 29% (two out of seven) were performed due to placental abruption [52].

Maternal mortality
Most papers quote a mortality rate of 0–3.8% among admitted pregnant trauma patients [36,37,44,54,55]. Older case series described a mortality rate reaching 10% in this population [56]. A Swedish population-based study found that MVA during pregnancy caused 1.4 maternal fatalities per 100,000 pregnancies (15 out of 2240 MVA cases) [38]. Maternal mortality was 5.6% among cases with major or fatal injury, and 0.872% among cases including minor injury. Within the subset of pregnant trauma patients who require CD in proximity to the injury, maternal mortality is much higher (28.1%; nine out of 32 maternal deaths). However, these trauma patients are usually severely injured; Morris et al. documented an ISS of 25–39 in two-thirds of these trauma patients and an ISS over 40 in the rest [53].

Motor vehicle accidents caused 29.4% of all pregnancy-related deaths in a Swedish study of maternal deaths over a 10-year period [38]. Maternal mortality is related to the presence of head injury [56], lower Glasgow coma scales (GCSs) [46,53], internal injuries [45], shock on admission [53], ISS over 8 [45] and maternal age of 41 years or older [45]. Lack of seat belt use was linked to 75% of maternal deaths in one study, leading the authors of this paper to conclude that this was the most important modifiable risk factor [56].

Perimortem CD in traumatic cardiac arrest is highly controversial. Perimortem CD should only be considered in cases where the fetus is probably viable; at 23–24 weeks gestational age. This practice was introduced after it was put forward that cardiopulmonary resuscitation is ineffective in the third trimester of pregnancy due to altered maternal anatomy and physiology [57]. Based on data demonstrating improved maternal survival when CD was performed within 4 min of cardiac arrest for any cause, this standard of care was adopted to trauma [57]. A review of 20 years of case reports on all perimortem CDs (traumatic, cardiac and embolic) concluded that CD profoundly impacted not only neonatal viability, but also maternal hemodynamic condition [58]. Conversely, a recent study of all maternal cardiac arrests occurring in the Netherlands noted similar maternal survival with [17% (2 out of 12 women) and without [14%; six out of 43 women] perimortem CD. However, the arrest was traumatic in only one case in this study and two-thirds of the CDs (eight out of 12) were performed only 15 min after the arrest [59].

Traumatic fetal morbidity & mortality
There are several potential mechanisms of fetal injury during maternal trauma: the fetus may sustain a direct traumatic injury, penetrating or blunt. Spontaneous preterm delivery as a direct result of the trauma or preterm delivery due to premature rupture of membranes, placental abruption or uterine rupture (all secondary to the trauma) can also affect fetal outcome. Finally, the indirect effects of maternal injury – anemia, hypoxemia and/or hypovolemia – are not well tolerated by the fetus.

Fetal & neonatal morbidity
Reported rates of fetal morbidity vary between series, dependent upon the definition of fetal injury and the population studied. Table 2 details the rates of maternal and fetal complications.
Fetal morbidity appears to be related to the severity of maternal injury but even with minor maternal injury severe fetal injury can occur [33,36,60,61]. A study examining all pregnant trauma admissions in Washington State demonstrated increased rates of neonatal hypoxia and respiratory distress syndrome after nonsevere maternal injury when compared with uninjured women. Further analysis of this cohort after exclusion of preterm pregnancies continued to demonstrate an increased risk of abruptio, infant hypoxia and fetal death [33]. Severe maternal injury is associated with an increased risk of placental abruption, CD and multiple adverse infant outcomes (e.g., premature delivery, low birth weight and fetal distress) [33,36].

Late fetal morbidity associated with trauma during pregnancy
It is increasingly recognized that the risk of an adverse fetal outcome extends beyond the admission immediately following trauma. Higher rates of preterm deliveries and low birth weights have been observed in deliveries occurring after hospital discharge [26,45,62]. One study compared women who delivered during their trauma admission (n = 2494) with women who did not deliver during trauma admission (n = 7822), and with nontrauma pregnant controls. Women who sustained trauma but did not deliver during the same admission had 20% more preterm deliveries, 56% higher placental abruption rates and 38% increases in low birth weight compared with uninjured control women [45]. It also appears that the severity of injury increases the risk of late fetal complications: a retrospective cohort study compared the risk of preterm delivery and low birth weight in injured patients (ISS >0) and those without identified injury (ISS = 0). All patients were discharged to return home after the trauma. Injured patients had a higher risk for both outcomes, and the risk was higher with increasing injury severity and among those injured early in gestation [62].

Fetal & neonatal mortality
Fetal mortality is reported after trauma admission in 0–25% of patients [26,33,45,54]. The highest rate (25%) was reported in a subset of women who required immediate CD after the trauma [53]. A more recent study comparing the risk of fetal/neonatal death in pregnant MVA patients to the risk during pregnancy uncomplicated by involvement in an MVA demonstrated that fetal mortality occurred in 1.2% (27 out of 2270) and neonatal mortality in 0.6% (13 out of 2270) [38]. MVA patients had an increased risk of intrauterine fetal death (OR: 3.55) compared with those uninjured in an MVA [38]. The incidence of fetal/neonatal death among all pregnant MVA patients in the USA is 3.7 per 100,000 population [26]. MVAs are one of the leading causes of injury-related fetal deaths [24,63,64]. Weiss et al. described 240 traumatic fetal injury deaths (based on death certificates from 16 US States between 1995 and 1997) [63]; MVAs accounted for 82% of cases with a known mechanism of injury. Extrapolating these data to the entire USA led to an approximation of 143 fetal deaths per year. The authors of this paper assumed that their data underestimated the incidence of traumatic fetal death; therefore, they concluded that it is likely that fetal death occurs at a higher frequency than infant death from MVA.

Although fetal loss is much less common after minor injuries in pregnant patients, nonsevere maternal injuries are much more common than life-threatening maternal injury. Data regarding the prevalence of fetal loss after relatively minor trauma in pregnancy are contradictory. The largest study relating to this issue describes 78 fetal deaths, 64% of which occurred when ISS in the pregnant trauma patient was lower than 9 [45]. When demise occurred during the trauma admission, 53% of the pregnant trauma patients (28 out of 53) had ISS an higher than 8. However, fetal demise after hospital discharge was more common (88%) when ISS in the pregnant trauma patients was lower than 9 (22 out of 25 patients) [45].

A population-based study in Sweden found that 33% (13 out of 40) of fetal demises occurred with minor trauma [38]. Nonetheless, it is clear that as maternal injury severity increases, the proportion of fetal/neonatal deaths also increases [45]. Severe maternal injury (as measured by higher ISS) predicts fetal demise [26,33,34,45,54]. Fetal loss after trauma often follows maternal hemodynamic instability [34,53,63]. Fetal death has been found to be associated with an earlier gestational age at the time of maternal injury. The type of injury is also associated with fetal mortality; the OR for demise was 6.7 after internal injury (95% CI: 2.7–16.7) and 4.81 after open injury (95% CI: 2.1–11.3) [45]. Most importantly, up to 40% of fetal deaths and 42% of traumatic fetal/neonatal deaths are associated with placental abruption [26,63]. Fetal death rates in cases of placental abruption may be as high as 75% [34].

Injury prevention in the pregnant trauma patient
Seat belts and airbags are the two preventive measures of value in motor vehicle accidents.

Seat belts
The role of seat belts in a low-impact collision was recently examined through simulation on dummies; proper seat belt use reduces abdominal pressure and prevents contact with the steering wheel during collisions [65]. Data from the US National Automotive Sampling Crashworthiness System (425 pregnant women, 11,972 nonpregnant women) showed similar seat belt use profiles in pregnant and nonpregnant women; proper use was documented in 59%, use in general was documented in 18%, improper use was documented in 3% and no use in 14% of pregnant cases [19].

Maternal mortality
A 10-year study of all maternal deaths in New Mexico State (USA) found 97 MVA-associated deaths, and lack of seat belt use was linked to 75% of these deaths. The authors of this paper concluded that this was the most important modifiable risk factor [66]. Among the six cases of MVA-associated maternal deaths identified in a 10-year retrospective chart review performed in a single US level 1 trauma center, five were associated with lack of restraints [54].

Fetal mortality
Improper or lack of seat belt use has been associated with fetal demise [23,34]. Retrospective logistic regression of statewide data (n = 8938) in the USA examined the association between fetal...
death and use of seat belts; women who did not wear seat belts had significantly higher risks (threefold) of fetal death [23]. A retrospective study performed in a level 1 trauma center (n = 271) identified lack of restraints to be significantly predictive of fetal death (eight out of 11 fetal deaths were in unrestrained pregnant patients) [34].

Maternal & fetal morbidity
Seat belt use may prevent maternal and fetal morbidity. In the aforementioned logistic regression analysis, pregnant women who were unrestrained during involvement in an MVA were more likely than women not involved in MVAs to experience excessive bleeding or deliver a low-birth-weight infant [23]. A retrospective in-depth review of pregnant MVA patients (n = 57) revealed that in 29% of the cases where restraints were used correctly there was an adverse fetal outcome, compared with 50% of cases with improper use of seat belts and 80% with unrestrained pregnant women [67].

Airbags
Data from the US National Automotive Sampling Crashworthiness System showed a similar likelihood of airbag deployment in pregnant and nonpregnant women. Airbags were deployed among 15% of pregnant and 13% of nonpregnant women [19]. The impact of airbag deployment on pregnant women injured in an MVA was unclear until recently. Most of the literature constituted case reports and small case series. In 2010, a retrospective cohort study on the effect of airbag availability and deployment on adverse pregnancy outcomes found that after controlling for confounders, outcomes were similar in pregnant women injured in vehicles equipped (n = 2207) or not equipped with airbags (n = 1141) [68]. This similarity in outcomes remained constant when the comparison was narrowed to women involved in an MVA with a deployed (n = 198) or undeployed airbag (n = 622) as well [68].

Predicting outcomes & the recommended observation period
Identifying the pregnant trauma patient at risk for a poor outcome could enable early implementation of preventive measures, which would hopefully reduce morbidity and mortality. Concomitantly, identifying the population subset with good outcomes could prevent excessive testing and observation, and allow early discharge from hospital. However, it is difficult to draw clear conclusions regarding outcome prediction for pregnant MVA patients; most reports do not follow Utstein guidelines (guidelines originally designed to standardize reporting of cardiac arrest by emergency medical services that were later adopted by the International Trauma Anesthesia and Critical Care Society for reporting of trauma) [69]. The definition of outcomes in these reports is not uniform, the selection of predicting variables differs between publications and most studies addressing this challenge are insufficiently powered (i.e., included a small population). Thus, almost every variable that has been suggested to correlate with outcome has been challenged.

Despite these difficulties, several variables seem to be consistently linked to adverse maternal and/or fetal outcomes after MVA trauma (Table 3). Demographic characteristics correlating with poor outcome include advanced maternal age and advanced gestational age (>35 weeks), primiparity and high-risk pregnancy. MVA characteristics for fetal death or low birth weight include ejection from the vehicle, pedestrian or motorcycle injury, and lack of seatbelt use. Injury characteristics correlating with maternal death, fetal death and poor fetal outcome include abdominal and pelvic injury, intracranial injury, internal organ injury, open injury and loss of consciousness. Monitoring findings that predict fetal death include maternal tachycardia, low GCSs and hypotension and abnormal FHR.

In a retrospective cohort study of all trauma admissions in California (USA) risk factors for maternal death included maternal age over 41 years (OR: 2.8), ISS higher than 9 (OR: 14.6), internal injury (OR: 15) or intracranial injury (OR: 11.1) [45]. In this population-based study fetal mortality was also predicted by advanced maternal age (>41 years; OR: 1.97), and internal injury (OR: 6.7) or open injury (OR: 4.8) [45].

Fetal death is associated with other variables: a population-based study of data from Washington State compared 294 injured pregnant trauma patients with 12,578 uninjured pregnant women [33]. Higher ISS was associated with fetal death (OR: 10.7), but non-severe injury was also associated with fetal demise (OR: 5.1). Another multicenter 5-year US-based study assessed the predictive value of physiologic variables in 372 injured pregnant trauma patients [44]. Maternal ISS (higher), maternal GCS (lower) and maternal hypotension were all associated with fetal demise [44].

Current American College of Surgeons (ACS) and American Congress of Obstetricians and Gynecologists (ACOG) guidelines recommend a minimum observation period of 2–6 h for pregnant women after trauma, unless there are symptoms suggesting placental abruption, fetal distress or serious maternal injury. During this observation period, ultrasound examination is recommended in all pregnant trauma patients and FHR monitoring in all pregnant trauma patients with a gestational age over 20 weeks [2,3].

The recommended minimal observation period is based on little literature; several studies demonstrated that discharge from hospital after a 6-h observation period is allowable for a select group of pregnant trauma patients [34,70,71]. Curet et al. identified a group of factors (ejections, motorcycle and pedestrian collisions, maternal death, maternal tachycardia, abnormal FHR, lack of restraints, ISS >9, gestational age >35 weeks and assaults), which, when absent, allowed patients to be monitored for only 6 h prior to discharge [34]. A small (n = 125) retrospective study demonstrated that the combination of external fetal monitoring and ultrasound identified all pregnancy-related trauma complications [71]. A recent study of risk factors for abruption and adverse pregnancy outcomes after minor trauma noted that there was only a single case of placental abruption among 256 pregnant trauma patients and that 19.4% (49 out of 256) of composite adverse outcomes could not have been predicted [39]. The author concluded that the extensive evaluation routinely performed after minor trauma in pregnancy should thus be re-evaluated [39].
Table 3. Variables predicting maternal and fetal mortality and morbidity in pregnant trauma patients.

<table>
<thead>
<tr>
<th>Predictive of</th>
<th>Variable type</th>
<th>Variable</th>
<th>n</th>
<th>OR</th>
<th>95% CI</th>
<th>p-value</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maternal death</td>
<td>Demographic characteristics</td>
<td>Maternal age &gt;41 years</td>
<td>10,316</td>
<td>2.86</td>
<td>1.6–5.1</td>
<td>0.000</td>
<td>[55]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Intracranial injury</td>
<td>11.1</td>
<td>1.6–76</td>
<td>0.014</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Internal injury</td>
<td>15.0</td>
<td>1.9–117</td>
<td>0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>ISS &gt;9</td>
<td>14.6</td>
<td>1.5–143</td>
<td>0.002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fetal death</td>
<td>Demographic characteristics</td>
<td>Maternal age &gt;41 years</td>
<td>10,316</td>
<td>1.97</td>
<td>1.8–2.2</td>
<td>0.000</td>
<td>[55]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ejection from vehicle</td>
<td>271</td>
<td>32.8</td>
<td>7.5–144.5</td>
<td>0.014</td>
<td>[31]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Motorcycle or pedestrian</td>
<td>6.9</td>
<td>1–4.68</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Use of seat belt</td>
<td>0.23</td>
<td>0.71–0.742</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Internal injury</td>
<td>10,316</td>
<td>6.67</td>
<td>2.7–16.7</td>
<td>0.000</td>
<td>[55]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Open injury</td>
<td>4.81</td>
<td>2.1–11.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maternal pulse &gt;110 bpm</td>
<td>271</td>
<td>12.6</td>
<td>4.3–37.2</td>
<td>0.01</td>
<td>[31]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maternal ISS &gt;8</td>
<td>271</td>
<td>46.5</td>
<td>12.3–175.6</td>
<td>0.010</td>
<td>[31]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maternal ISS 25.6 vs 7.4</td>
<td>372</td>
<td>30.2</td>
<td>9.4–97.1</td>
<td>&lt;0.001</td>
<td>[42]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maternal ISS &gt;8</td>
<td>294</td>
<td>9.0</td>
<td>2.1–37.1</td>
<td></td>
<td>[31]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maternal GCS 10 vs 14.5</td>
<td>582</td>
<td>9.0</td>
<td>2.1–37.1</td>
<td></td>
<td>[31]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low maternal blood pressure</td>
<td>372</td>
<td>Maternal mortality: 23 vs 2%</td>
<td>&lt;0.001</td>
<td>[42]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>FHR 0–120 bpm</td>
<td>271</td>
<td>40.5</td>
<td>6.7–243.6</td>
<td></td>
<td>[31]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FHR &lt;110 bpm</td>
<td>372</td>
<td>Prevalence in fetus nonsurvivors vs survivors: 50 vs 9%</td>
<td>&lt;0.001</td>
<td>[42]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Placental abruption</td>
<td>271</td>
<td>109.3</td>
<td>24.2–493.2</td>
<td></td>
<td>[34]</td>
</tr>
<tr>
<td>Poor fetal outcome (fetal death or hydrops)</td>
<td>Demographic characteristics</td>
<td>Maternal age 28.3 vs 23.6 years</td>
<td>294</td>
<td>1.7</td>
<td>1.64–1.76</td>
<td>0.037</td>
<td>[34]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pelvic injury</td>
<td>Poor fetal outcome: 71.4 vs 2.8%</td>
<td>0.0001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Loss of consciousness</td>
<td>Poor fetal outcome: 71.4 vs 34.9%</td>
<td>0.0001</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>ISS 16.3 vs 3.2</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Low birth weight</td>
<td>Demographic characteristics</td>
<td>First delivery</td>
<td>8938</td>
<td>1.7</td>
<td>1.64–1.76</td>
<td>0.0001</td>
<td>[22]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Smoking during pregnancy</td>
<td>2.54</td>
<td>2.42–2.66</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low weight gain during pregnancy</td>
<td>2.43</td>
<td>2.32–2.53</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Presence of medical risk factor</td>
<td>3.03</td>
<td>2.93–3.13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>No use of seat belt</td>
<td>1.3</td>
<td>1.03–1.64</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uterine contractions, preterm labor, vaginal bleeding</td>
<td>Demographic characteristics</td>
<td>Gestational age &gt;35 weeks</td>
<td>271</td>
<td>3.7</td>
<td>2.1–6.7</td>
<td>[31]</td>
<td></td>
</tr>
</tbody>
</table>

ED: Emergency department; FHR: Fetal heart rate; GCS: Glasgow coma scale; ISS: Injury severity score; MVA: Motor vehicle accident; OR: Odds ratio.
Gestational age over 35 weeks, assaults and pedestrian collisions are also predictive of developing uterine contractions, preterm labor and/or vaginal bleeding, with a resultant increase in the rates of premature delivery [34].

Management of the pregnant trauma patient

In a targeted search of the websites and publications of the Royal College of Obstetrics and Gynecology, the Society of Obstetricians and Gynecologists of Canada, the Royal Australian and New Zealand College of Obstetrics and Gynecology, the ACS and the ACOG, only two guidelines were found to address management of the pregnant trauma patient (Table 4).

Management of the pregnant trauma patient should follow Advanced Trauma Life Support (ATLS) management guidelines for general trauma victims [2]. The primary survey should be based on a systematic airway, breathing and circulation approach. The only obstetric consideration at this point should be the likelihood of maternal instability due to the presence of obstetric complications. The secondary survey should include the usual in-depth physical assessment of injuries, laboratory tests, diagnostic imaging and therapeutic procedures. It is at this point that the uterus and fetus must be evaluated. The following paragraphs provide more detail on issues unique to the management of the pregnant trauma patient.

Trauma team activation

A study of trauma team activation calls (single center: 5 years) noted that in most pregnant trauma patients (188 out of 352; 58%), the sole criteria for trauma team activation was pregnancy [40]. Apparently this is common practice. However, several studies have challenged this approach. In this study none of the trauma patients was admitted to the trauma service. Greene et al. demonstrated that when pregnancy was the sole criteria for trauma team activation, the trauma patients evaluated had lower ISSs (range: 1–6 vs 1–27 in nonpregnant trauma patients), 94% of pregnant trauma patients with a gestational age under 20 weeks were never admitted (33 out of 35 patients) and no patient was admitted to the surgical service [40]. Aufforth et al. demonstrated that when pregnancy was the sole criteria for trauma team activation, the mean trauma patient ISS was 1.053 with a range of 1–4 (i.e., these trauma patients were never severely injured), CD took place in 3.5% of the patients (two out of 57; both CDs were for term pregnancies) and no trauma patient required any other surgical intervention [52]. If a decision is made to activate the trauma team based on pregnancy as the sole criteria, it is important to take into consideration that such low rates of significant injury could erode adherence to trauma protocol.

Although a multidisciplinary team approach is recommended for pregnant trauma patients, the general surgeon should always be responsible for overall case management [2,3]. This principle remains valid even if a decision is made not to activate the trauma team. The obstetrician should act as consultant until it is clear that the cause of maternal instability is solely obstetric.

Physical examination

Management of the pregnant trauma patient should follow standard ATLS management guidelines [2]. The primary survey, and resultant resuscitative efforts, should thus be similar. Initial examination by a general surgeon and documentation of vital signs is advocated at this early stage of treatment [2,3]. Determining the presence of a pregnancy and rough estimation of the gestational age can be performed by palpation of the uterine fundus from the second trimester of gestation onwards. All female patients of childbearing age arriving at the emergency room following trauma should have a pregnancy test as part of this assessment. As previously noted, earlier preterm

| Table 3. Variables predicting maternal and fetal mortality and morbidity in pregnant trauma patients (cont.). |
|-----------------|-----------------|--------|--------|--------|--------|
| Predictive of   | Variable type   | Variable | n     | OR    | 95% CI | p-value | Ref.  |
| Placental abruption | Physiologic variables at ED arrival | ISS >8 | 582   | 9     | 4.7–17.0 | [33]    |
| Fetal distress | Physiologic variables at ED arrival | ISS >8 | 582   | 2.1   | 1.3–3.5 | [33]    |
| Cesarean delivery | Physiologic variables at ED arrival | ISS >8 | 294   | 1.6   | 11.2–4.4 | [30]    |
| Preterm delivery | Physiologic variables at ED arrival | ISS >8 | 582   | 3.8   | 1.4–10.3 | [33]    |
| Respiratory distress syndrome | Physiologic variables at ED arrival | ISS >8 | 582   | 3.8   | 1.4–10.2 | [33]    |

ED: Emergency department; FHR: Fetal heart rate; GCS: Glasgow coma scale; ISS: Injury severity score; MVA: Motor vehicle accident; OR: Odds ratio.
Table 4. Recommendations of the American College of Surgeons and the American College of Obstetricians and Gynecologists for treatment of the pregnant trauma patient.

<table>
<thead>
<tr>
<th>Treatment recommendations</th>
<th>ACS</th>
<th>ACOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multidisciplinary team approach (including general surgeon)</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Vital signs: measurement and documentation</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Documentation of GCS</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Pelvic examination</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Minimum observation period of 2–6 h</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Hospital admission in certain circumstances</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Fetal heart rate monitoring and ultrasound examination for fetal evaluation</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

ACOG: American College of Obstetricians and Gynecologists; ACS: American College of Surgeons; GCS: Glasgow coma scale.
Data taken from [2,3].

The maternal heart is displaced to the left and upward, and rotated somewhat on its long axis secondary to diaphragmatic elevation. These changes can increase the size of the radiographic cardiac silhouette. The cardiac silhouette on plain film may also be increased secondary to the presence of benign pericardial effusion [77].

Ultrasound imaging
Sonography is a well-established imaging technique during pregnancy and has no adverse effects on the fetus [78]. The accuracy of focused abdominal sonography for trauma in detecting intra-abdominal injury during pregnancy is similar to that observed in nonpregnant women [79–81]. The advantages of ultrasound evaluation in pregnant trauma patients include avoidance of ionizing radiation exposure, the flexibility of bedside evaluation enabling provision of diagnostic information in patients too unstable for transport to the CT scanner and the ability to provide information important for both trauma and obstetric management (i.e., determination of gestational age, confirmation of FHR, assessment for multiple gestations, identification of placental location and possibly the presence of abortion) [79]. However, it is important to be aware of the limitations of bedside sonography; although it provides valuable information regarding pelvic and intrauterine structures, sonography performs poorly for the diagnosis of placental abruption (50–80% of cases can be missed) [76].

CT scanning
The ACS guidelines state that similar indications exist for CT scanning in pregnant and nonpregnant trauma patients [2]. ACOG guidelines suggest that CT scanning should only be used to evaluate those pregnant patients who have suffered significant trauma [3]. A recent publication suggested that CT scanning provides added value due to the ability to identify patients with placental abruption (sensitivity: 86% [six out of seven abruptions detected correctly]; specificity: 98% [53 out of 54 nonabrupted placentas correctly identified]; overall accuracy: 96%) [82]. However, the suggestion that in utero exposure to radiation may be associated with a small increased risk of childhood leukemia (absolute risk ~one in 2000) should not be disregarded [83].

Magnetic resonance imaging
The advantages and safety profile of MRI have been described extensively in the context of suspected acute appendicitis during pregnancy [84,85]. Two case reports suggest that MRI may have advantages over other imaging modalities in the diagnosis of uterine rupture [86,87]. Both reports describe uterine rupture diagnosed by MRI, despite inconclusive ultrasound scans. Most imaging modalities rely on indirect and/or nonspecific findings in the diagnosis of uterine rupture. MRI enables direct visualization of the uterine wall defect/tear, resulting in a more definitive diagnosis. MRI is also
less operator dependent and provides a more comprehensive study with a larger field of view in comparison to ultrasound. Unlike CT scanning, MRI does not expose the patient and the fetus to ionizing radiation and imaging can be performed in multiple planes without the need for reconstruction. Finally, MRI enables better evaluation of soft tissue than either ultrasound or CT scanning. Nonetheless, a survey on methods of imaging in different clinical situations during pregnancy revealed that only a handful of institutions are using MRI for imaging in maternal trauma (as opposed to pregnant women with abdominal complaints) [88]. It is probably for this reason that guidelines on imaging during pregnancy suggest that MRI is not a practical option for rapid evaluation in trauma [84].

Fetal monitoring

Early recognition of fetal distress may improve fetal outcome. Uterine activity and FHR monitoring should begin once maternal stability is established [2,3]. In pregnancies with a gestational age over 20 weeks, cardiotocography should be used to monitor uterine activity; excess activity suggests placental abruption or preterm contractions that may result in preterm birth. Recurrent uterine contractions suggest premature labor if accompanied by cervical change [2]. Pregnancies beyond 24 weeks are viable and fetal monitoring should be used when the mother is stable enough during the secondary survey. Abnormal FHR may be the first sign of maternal hemodynamic compromise due to blood shunting from the uterus [89,90]. If a nonreassuring FHR pattern is detected, an attempt should be made to improve fetal oxygenation; the mother should receive supplemental oxygen and hydration, and be positioned in the left lateral decubitus position. If no improvement is observed, delivery should be expedited, most likely through CD.

The duration of fetal monitoring is somewhat controversial. Continuous fetal monitoring best identifies acute fetal distress [91]. Intermittent monitoring is less likely to detect adverse events at the time of occurrence. Most authorities concur that an initial 2–6 h continuous monitoring period suffices since approximately 80% of abruptions will occur during this time [3]. The remaining 20% of abruptions occur within 24 h of the trauma; these typically present with persistent contractions [92,93].

Trauma patients with a viable fetus should be monitored for 2–6 h provided there is no evidence of contractions, preterm labor, vaginal bleeding or other signs suggesting fetal loss. If any of these signs or symptoms is present, or if the trauma patient requires admission for treatment of maternal injuries, has sustained severe head injury or requires general anesthesia, monitoring should continue for at least 24 h. During this period, checks for uterine contractions/irritability, vaginal bleeding, premature rupture of membranes and a nonreassuring FHR pattern should be carried out [2,3]. The utility of continuous fetal monitoring beyond 24 h is limited. Prolonged monitoring is essentially unnecessary unless placental abruption is suspected [92,93].

Laboratory testing

Laboratory panels should be ordered according to trauma protocol. Neither ACS nor ACOG guidelines mention blood sampling in the pregnant MVA patient. The clinician should be aware that standard laboratory values during pregnancy are somewhat different from the norm. Anemia, thrombocytopenia and increased creatinine clearance are some of the common changes that occur during pregnancy. A full description of these laboratory differences is presented elsewhere [94].

Fetomaternal hemorrhage occurs in 10–30% of pregnant trauma patients [95]. Rh-negative pregnant trauma patients should receive Rh–IgD within 72 h of injury to prevent future Rh alloimmunization [96]. The Kleihauer–Betke (KB) test, which can determine whether fetal blood has entered the maternal circulation (fetomaternal transfusion), has been a subject of controversy in recent years [97]. In Rh-negative mothers, the KB test can provide a rough estimate of the volume of fetomaternal hemorrhage. The clinical utility of KB testing in Rh-positive mothers is uncertain [97]. A retrospective study exploring the value of KB testing in pregnant trauma patients revealed that a positive KB test (regardless of maternal Rh status) was the single predictive risk factor for preterm labor, with 100% sensitivity and 96% specificity for uterine contractions [98].

Indications for admission

Hospital admission is recommended for pregnant trauma patients who present with signs and symptoms suggestive of impending complications. These include abdominal tenderness, pain or cramping, obstetric findings such as vaginal bleeding, uterine irritability, evidence of changes in or absence of FHR, and/or amniotic fluid leakage [2]. The pregnant trauma patient may be discharged from hospital provided she has sustained only minor trauma, FHR tracing is reassuring and the patient is not experiencing any contractions. Complaints of uterine tenderness, vaginal bleeding or rupture of membranes suggest further hospital observation is required. Detailed instructions regarding the indications for returning to medical care should always be provided upon discharge.

Obstetrical follow-up of discharged patients

To date, women who are sent home after hospital admission for a MVA are managed as though the trauma had never occurred – no unique follow-up regime is required. It is not clear whether this practice should be changed: although two recent studies have shown an increased risk for poor obstetric outcomes in this population (especially in the more severely injured women) [45,62], it remains unclear whether the benefit of performing additional studies justifies the risks and the costs. It may be best to regard these women simply as a population with an increased risk of preterm delivery with according follow-up: serial cervical length examinations, interval growth studies and, if deemed necessary, administration of antenatal steroids similar to women with a history of preterm delivery [99].

Continuing maternal organ support to prolong gestation & attain fetal viability

Maternal brain death is most often followed by a relatively predictable onset of cardiovascular instability, adrenal insufficiency and hypothyroidism, poikilothermia, sepsis and arrhythmias, resulting in eventual cardiac arrest [100–103]. However, isolated
maternal brain death may lead to a major quandary; should an attempt be made to continue maternal somatic support in order to attain fetal viability? The ‘Erlanger Baby’ controversy, which led to international debate, demonstrates the complexity of such decisions [104]. Debatable issues include both ethical and medical dilemmas. The mother and the fetus are two distinct organisms. Relinquishing the maternal right to die can only be justified if there is a reasonable likelihood of salvaging the fetus.

To date, prolongation of maternal somatic function is mostly experimental. The frequency of unsuccessful support of pregnancy after maternal brain death remains unknown, as these cases are never published [105]. An increasing body of evidence is being accumulated on sustaining organ function following brain death with the intent of organ donation. However, these cases rarely require prolonged support and only one case report described the management of a pregnant patient for combined organ donation and delivery [106]. Several years ago, Powner and Bernstein summarized ten case reports of somatic support after maternal brain death until successful delivery [107]. Only a handful of new cases have been published since [108,109].

A gestational age of 32 weeks is generally considered optimal for delivery; the risk for neonatal intraventricular hemorrhage observed after this age is reduced significantly. In early pregnancies achieving this gestational age is hardly an option. Continuing pregnancy until fetal viability (i.e., 24 weeks) may be a reasonable medical alternative in such cases. The likelihood of success in attaining fetal viability depends mainly on the duration of time maternal somatic function must be maintained. The longest period of successful maternal somatic support following brain death in published literature to date is 107 days [110].

Knowledge gaps & future clinical research priorities

This article includes data gathered from different sources and different types of studies over a period of approximately 20 years. Aside from the difficulties stemming from comparing studies published over a lengthy period of time, other difficulties stem from the quality of published studies in this field – many studies are of lower levels of evidence. Case reports and case series from selected trauma centers that do not represent the entire pregnant population and only relatively few rigorously designed, population-based studies have been performed on risk factors for, and outcomes from, trauma in pregnancy. These limitations in most studies of trauma during pregnancy restrict the authors’ ability to generalize best practices for management. Hence, the reliance on expert opinion, including the ACOG educational bulletin and the ATLS guidelines. No other major obstetric, anesthesia or surgical associations have issued guideline on standard of care in such circumstances. Typical trauma study limitations include: the broad spectrum of disease states included in this definition, the retrospective nature of data collection and analyses, inconsistencies in population denominators, in criteria for defining obstetric complications, in length of follow-up and definition of outcome end points.

As trauma systems evolve, the rate of preventable deaths is reduced. The result of this improvement is a shift in quality-improvement programs from analysis of outcomes to analysis of complications and the efficiency of care (via audit and performance indicator analysis). To date, most studies of pregnant trauma patients described the epidemiology of maternal and fetal morbidity and mortality. Most studies do not adhere to the Utstein guidelines on reporting of trauma, hence comparisons are limited and there is little likelihood of reaching solid conclusions regarding risk factors, treatment efficacy and outcomes. Further studies in this field should examine processes as well as outcomes, and should adhere to reporting recommendations. Key areas of trauma care should be identified (e.g., prehospital, resuscitative care and definitive care), and the important outcomes and processes in each area should be defined, mapped and monitored. It is crucial that future studies include population-based methods and standardized data collection. These new, good-quality, scientific data are needed regarding prevention, recognition, evaluation, treatment, monitoring, outcomes and education. Scientific advances can only be made if such new data will be presented. Standardization of reporting is a prerequisite. Lacking standardization, published data cannot be analyzed or compared.

Some areas of care may require special attention. Examples include recognition of injuries that do not require special monitoring or care versus factors associated with poor outcomes, the extent of work-up and required lengths of observation, rates of adherence to guidelines and the efficacy of training methods, long-term outcomes and so on. Further research should address these dilemmas and provide quality data targeted to solve these issues.

Expert commentary

Trauma during pregnancy is a common event, potentially affecting both mother and fetus. A systematic approach to trauma patients reduces morbidity and mortality, and is thus advocated in pregnant women as well, although few data exist on the correlation between process and outcome in this population. Although several risk factors seem to be associated with increased morbidity and mortality, differences in study methods make them contestable. Viewing the mother (and not the fetus) as the object of treatment may be exigent; trauma team activation for pregnancy as a sole criteria is common and reflects caregiver concerns for fetal wellbeing, as do increased transport to hospital and admission rates. Familiarity with triage priorities and ATLS treatment guidelines, understanding the physiology of pregnancy, the ability to recognize and treat disruption of the supportive uterine environment, and awareness of potential late complications are all prerequisite for provision of quality care to the pregnant trauma patient. Current training programs and guidelines do not address most of these issues.

Five-year view

An explosion in research reports in the field of maternal trauma has yet to come. Most trauma studies are retrospective analysis of existing data. While important data have been gleaned from these analyses, future research should be prospective and should focus on processes as well as outcomes. The outcomes sought should reach beyond the initial admission period; previously unsuspected relationships between maternal injury and neonatal complications have been demonstrated in recent publications.
Increasing experience with the pregnant population in the critical care environment may provide important information regarding management and prognosis in severely injured pregnant trauma patients. A growing body of evidence regarding maintenance of the uterine environment despite maternal brain death may provide important insights into the likelihood of late fetal salvage.

The next 5 years will hopefully bring more studies with a focus on standardized retrospective analyses and prospective well-designed multicenter studies that pay careful attention to the study population (population based). Two important areas of focus will be prediction of poor outcomes and the identification of injuries that do not require prolonged observation or hospital admission. Such developments will enable early discharge of trauma patients shortly after trauma and the timely treatment of pregnant trauma patients who require early intervention.

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### Key issues

- Trauma occurs in approximately one in every 15 pregnancies. Motor vehicle accidents are the leading cause of maternal injury.
- Physiologic changes that occur during pregnancy may imitate or mask shock symptoms.
- Expert multidisciplinary efforts should follow trauma guidelines that prioritize maternal airway support, breathing and circulation. The uterus and fetus should be evaluated only during the secondary survey.
- Viewing the mother (and not the fetus) as the object of treatment may be exigent. Trauma team activation for pregnancy as a sole criteria is common, as are increased transport to hospital and admission rates.
- A total of 38% of pregnant patient admissions are associated with delivery. Pregnancy-related morbidities encountered after trauma are mainly preterm (often cesarean) delivery, placental abruption and uterine rupture.
- In total, 2–6 h of observation with fetal monitoring are recommended for pregnant trauma patients that do not require admission.
- Risk factors for adverse maternal and/or fetal outcomes after motor vehicle accident trauma include advanced maternal and gestational age, primiparity, ejection from the vehicle, maternal tachycardia, low Glasgow coma scales and hypotension, abdominal and pelvic injury, intracranial injury, internal organ injury and abnormal fetal heart rate. Lack of seat belt use is probably the most important modifiable risk factor for maternal death.
- Severe fetal injury can occur with even minor maternal injury. A significant number of fetal deaths are associated with placental abruption. Antecedents to placental abruption include blunt trauma and maternal complaints of abdominal pain, severe contractions with pain disproportionate to the degree of cervical dilation and/or vaginal bleeding.
- If pregnant trauma patient death is imminent, perimortem cesarean delivery should be considered at gestational age over 24 weeks for both maternal and fetal benefit. Maternal somatic support will be needed until full-term pregnancy can be considered in selected cases.
- The increased risk of maternal and fetal complications continues after hospital discharge.

### References

Papers of special note have been highlighted as:

**••** of considerable interest

their impact on birth outcomes.


Prospective cohort study of the rate of and risks for abrasion and adverse pregnancy outcome after minor trauma during pregnancy.


Retrospective cohort study of obstetric patients for whom trauma team was activated. Outcomes were compared according to the indication for evaluation: either for physiologic, mechanic or anatomic criteria, or due to the presence of the pregnancy alone.


Retrospective cohort study of women admitted after trauma in California (USA), and also reported outcomes following hospital discharged from trauma hospitalization.


Injury in motor vehicle accidents during pregnancy: a pregnant issue

Review

When possible, the 2.5 and 97.5 percentiles were reported as the normal range.

**Website**

201 National Trauma Data Bank 2009: Annual Report