Trauma during pregnancy

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TRAUMA IN PREGNANCY is a relatively uncommon event, occurring in less than 1% of all trauma admissions in Australia.[1] Previous reports that trauma in pregnancy accounted for 6%–7% of trauma admissions in the United States[2,3] probably reflect a selection bias. While most traumatic injuries in pregnancy are minor, there can be serious implications for the fetus and mother. Trauma is an important cause of maternal mortality; accounting for up to 46% of all maternal deaths.[4] Management of the pregnant trauma patient poses specific challenges beyond the realm of usual trauma or obstetric care. There is a need to establish safe and effective protocols for monitoring the mother and fetus. This review provides an update on current management of trauma in pregnant patients.

Pattern of injury during pregnancy

Large published series on trauma in pregnancy are uncommon, but recent publications by Curet et al and Theodorou et al report on 271 and 80 patients, respectively,[5,6] adding significantly to our understanding. In Australia, blunt trauma accounts for nearly all trauma during pregnancy (Box 1),[7] whereas in the United States penetrating injuries account for up to 10%.[2]

Penetrating trauma in pregnancy, generally due to gunshot or stabbing, has a different injury pattern to blunt trauma. The size

Abstract

- The management of the pregnant trauma patient requires an understanding of the altered physiology in pregnancy and decisive action to avoid fetal loss when serious sequelae arise.
- Major trauma to a pregnant patient is uncommon in the experience of most obstetricians, who may underestimate the risk of serious complications, especially in the fetus.
- Hypotension, tachycardia, and contractions in the pregnant woman, in association with increased injury severity, indicate a high risk of fetal death. These patients should be monitored aggressively with cardiotocography for at least 24 hours. Patients without these findings should be monitored for 4 hours.
- Focused abdominal sonography for trauma and detailed ultrasound examination of the fetus provide the best means of assessing abdominal and pelvic injuries in pregnancy.
- Early caesarean section in conditions of fetal distress will improve outcome.

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of the uterus in pregnancy makes it the most likely organ to be injured, followed by the fetus and placenta. The gravid uterus may act to protect the abdominal viscera — only 18% of women with gunshots sustain visceral injury.[8] Buschbaum explains this on the basis that the uterine muscle acts as a buffer to absorb missile energy and so prevent injury to viscera beyond the uterus.[9]

Gunshot wounds commonly lead to fetal death, with a perinatal mortality of up to 70%.[9] Fetal trauma after stabbing injuries to the uterine cavity occurred in 13 of 14 such cases reported by Sakala and Kort, and 9 of 19 fetuses died after stabbings to the maternal abdomen.[10] Kaloo et al recommend that third trimester fetuses subjected to stabbing injuries should therefore be delivered promptly.[11]

Although the gravid uterus protects other viscera, stabbings into the upper abdomen can cause serious injury, especially to compressed loops of bowel or to the overlying diaphragm. The latter is particularly dangerous in pregnancy if unrecognised, because of the possibility of subsequent bowel strangulation, which has much higher mortality rates in pregnancy (25%–60%) than in the non-pregnant patient (16%–20%) (Box 2).[12]

Traumatic placental abruption may occur even when there are few other signs of trauma. Experiments have been conducted on pregnant baboons, which were subjected to decelerative forces (~20 G) typical of motor vehicle crashes.[12] Such forces produce very high intrauterine pressures (~550 mmHg). While the myometrium is elastic, the placenta is inelastic, leading to shearing forces between the two when high pressures are applied to the interface.

Because amniotic fluid transmits high pressures efficiently, "blast injuries" can follow blunt trauma, resulting in rupture of the uterine fundus, maternal diaphragm and liver, or specific intracavity fetal injury such as haemothorax, haemopericardium and intracranial haemorrhage.

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1: Causes of trauma in pregnancy in Australia

Motor vehicle collision: injuries to occupants	65%–75%
Falls	10%–20%
Motor vehicle collision: injuries to pedestrians	5%–15%
Assault	1%–10%

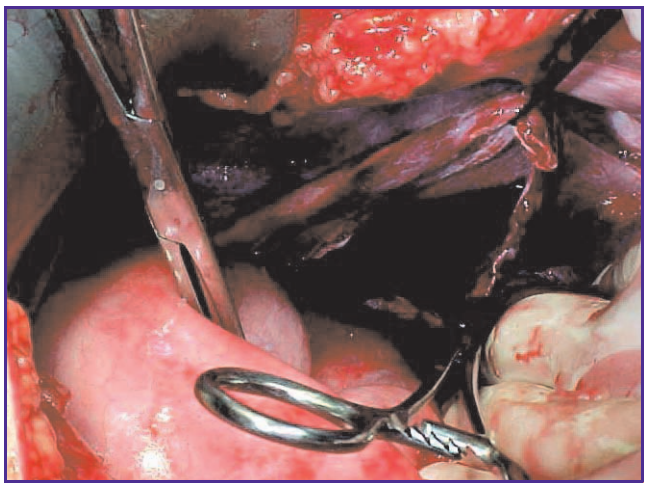
Even relatively minor trauma to the mother can carry a significant risk of fetal death. Abrupt deceleration sufficient to cause seatbelt injury such as this may cause placental abruption.
(Image source: www.trauma.org/imagebank/imagebank.html)

Physiological changes in pregnancy

Anatomical and physiological changes during pregnancy may mask or mimic injury or mean that physical signs are misinterpreted. These changes occur in cardiovascular, haematological, respiratory, gastrointestinal, urinary and endocrine systems. An outline of these changes is shown in Box 3.

The non-gravid uterus is intrapelvic, but it loses this protection as it expands out of the pelvis during pregnancy. The

2: Lacerated diaphragm



Unrecognised, such an injury poses a risk of strangulated bowel, which has a much higher mortality rate in pregnancy.[12]
(Image source: www.trauma.org/imagebank/imagebank.html)

3: Physiological changes in pregnancy

	Non-pregnant	Pregnant
Cardiovascular		
Pulse	70–80/min	Up by 10–15/min
Cardiac output	4.5 L/min	Up to 6.7 L/min
Systolic blood pressure	110 mmHg	Down by 5–15 mmHg
Haematological		
Blood volume	4000 mL	Up by 30%–50%
Plasma	2400 mL	Up to 3700 mL
Red blood cell volume	1600 mL	Up to 1900 mL
Haemoglobin	120–160 g/L	Down to 100–140 g/L
Haematocrit	37%–48%	Down to 32%–42%
White blood cell count	4.5–10.0 × 10^9/L	Up to 5.0–14.0 × 10^9/L
Respiratory		
Tidal volume	500 mL	Up by 25%
Functional residual volume	1200 mL	Down by 25%
Gastrointestinal		
Intra-abdominal pressure	Normal	Increased
Gastric emptying	Normal	Decreased

uterus increases in weight from 60 g to 1000 g by the end of pregnancy. Cardiac output increases from 4.5 L/min to almost 7 L/min. Blood volume increases by up to 50% by the 28th week of gestation. The protective effect of hypervolaemia allows the patient to lose up to 30% of blood volume before signs such as hypotension appear.[13] It is not uncommon for normal pregnant women to have remarkably low blood pressures, especially in the second trimester (eg, 80/40 mmHg). This must be taken in to account when assessing blood loss from trauma. Most of the electrocardiographic changes seen in pregnancy are due to anatomical changes in heart position, with left axis deviation of up to 15 degrees being common.

There is a greater increase in maternal plasma volume than in total red cell mass, resulting in the so-called "anaemia of pregnancy". There is an increase in the level of maternal plasma fibrinogen, as well as factors II, VII, VIII, IX and X, and a decrease in plasminogen activator levels. This is important to remember in any trauma situation where hypercoagulability and the risk of deep venous thrombosis are already increased.

Maternal–fetal unit

Fetal blood has a low partial pressure of oxygen, but fetal haemoglobin compensates for this by having a higher affinity for oxygen than maternal haemoglobin at any given partial pressure of oxygen. Oxygen transport in the fetoplacental unit is determined by uterine blood flow. Because of the passive uptake of oxygen, fetal oxygenation is not higher than that in the uterine vein.

Maternal assessment

When confronted with an injured pregnant patient, the mother should be attended to before the fetus, as optimal care of the mother optimises fetal outcome. Maternal assessment should follow guidelines laid out by the Early Management of Severe Trauma (EMST)/Advanced Trauma Life Support (ATLS) approach to trauma, with a detailed primary and secondary assessment. Trauma in pregnancy should be an indication for activating the comprehensive Trauma Team response.[14]

In relation to primary assessment, there are slight differences from the assessment of the non-pregnant patient. In particular, positioning of the pregnant patient is very important, especially in the third trimester. A gravid uterus causes vena caval compression and reduces venous return and cardiac output. It is therefore important to tilt the pregnant patient to the left by about 15°–30° and manually displace the uterine fundus to the patient's left. The patient should be tilted as an entire unit, maintaining stabilisation of the spinal column.

Comprehensive radiological assessment should be undertaken in spite of the concurrent pregnancy. In a conscious patient without distracting injuries, the cervical spine and pelvis can be cleared clinically. Pelvic fractures are associated with significant fetal loss.[15] The greatest risk to the fetus from radiation is during organogenesis between the fourth and eighth weeks of gestation. The dose likely to increase the baseline risk of childhood malignancy is 0.1 Gy; dosages below 0.1 Gy are not considered teratogenic.[8] By way of comparison, the radiation dose from a computed tomographic scan of the pelvis and abdomen is 0.03–0.1 Gy.

Ultrasound is a useful method of assessing the abdomen, with sensitivity and specificity in pregnancy approaching that for the non-pregnant trauma patient.[16] Goodwin and colleagues, in their review of focused abdominal sonography in trauma (FAST), reported two patients with injuries missed by FAST: free fluid in one, and a liver injury in the other. FAST rarely detects solid organ injuries, although for detection of free fluids it has a high specificity and sensitivity.[17]

FAST is the ideal investigation and triage tool for the pregnant patient. It is quickly performed and can be repeated serially to detect evolving intraperitoneal haemorrhage. In a haemodynamically unstable pregnant trauma patient, a finding of free intraperitoneal fluid should prompt an immediate laparotomy. Laparotomy should be performed through a midline incision, not a Pfannenstiel incision, to allow access to all parts of the abdomen.

A formal ultrasound has the potential advantage of being able to detect significant fetal injuries, but is less likely to detect abruption or uterine rupture, where its accuracy is only 50%.

If FAST is not available then diagnostic peritoneal lavage (DPL) can be used, using an open technique under local anaesthetic.[18,19] There are two potential problems with this technique: placement of the DPL catheter in the peritoneal cavity is always painful, even with local anaesthetic, and DPL can overestimate the degree of intraperitoneal haemorrhage, resulting in surgery that may be unnecessary and hazardous.

One of the best indications of maternal or placental injury comes from clinical observation. Clinical findings of placental

abruption may include vaginal bleeding, abdominal cramps, uterine tenderness, amniotic fluid leakage, and maternal hypovolaemia out of proportion to visible bleeding. Up to 2 L of blood can accumulate in the uterus, and this can be a cause of maternal shock. In a patient with intrauterine haemorrhage, the uterus may be larger than normal for gestational age. Changes in fetal cardiotocography, such as bradycardia, loss of beat-to-beat variation or sinusoidal patterns, may also indicate placental injury, fetal hypoxia or fetal blood loss. Ultrasound examination of the pregnant abdomen to detect free fluid is much more useful than clinical examination.

To avoid the risk of a delayed diagnosis or missed injury, tertiary survey should be undertaken within 24 hours of admission.[20]

4: Factors predicting fetal death in trauma

- Ejection from vehicle
- Pedestrian injury
- Lack of restraints
- Maternal tachycardia
- Maternal hypotension
- Maternal hypoxia
- Maternal contractions
- Abnormal fetal heart rate
- Injury severity score > 9

The risks of trauma in pregnancy

The pattern of serious injuries in pregnant women is different from that of non-pregnant trauma patients: injuries to the abdomen are more common than injuries to the head and chest. The possibility of domestic violence should be considered, especially where the injuries are inconsistent with their alleged cause.

The risk to the pregnancy in "minor" or non-catastrophic trauma is still significant, with preterm labour occurring in 8%, placental abruption in 1% and fetal death in 1%. For those with major trauma, maternal mortality is about 9%, [2] and the fetal death rate is 20% or greater.

About 5% of fetal injuries occur without injury to the mother.

Fetal assessment

The aim of fetal assessment is to detect fetal distress and reduce the risk of fetal loss. Some authors have in the past been unable to identify any significant risk factors relating to injury or patient physiology that would predict poor outcome.[21,22] More recently, other authors have identified a number of risk factors for fetal loss, including penetrating uterine injuries, severe maternal head injuries and maternal pelvic fractures, but each series identifies slightly different factors (Box 4).[5,6,23,24,25]

Any viable fetus of 24 weeks or more requires cardiotocographic (CTG) monitoring after maternal trauma. This includes patients with no obvious signs of abdominal injury. Pearlman has recommended a minimum of 4 hours of CTG observation to detect intrauterine pathology;[21] we would recommend 6 hours. This should be extended to 24 hours if at any time during the first 6 hours there is more than one uterine contraction every 15 minutes, uterine tenderness, non-reassuring fetal CTG monitoring, vaginal bleeding, rupture of the membranes or any serious maternal injury. Rogers et al studied 372 traumatic fetal deaths from several institutions. Sixty-one per cent were in patients undergoing continuous fetal monitoring, but seven fetuses with CTG abnormalities were saved by caesarean section.[25] Formal ultrasound of the fetus may provide important information,[3] such as the presence of liver injury[26] or intracranial haemorrhage.[27]

Most hospitals have limited experience in managing pregnant patients who are involved in trauma. Between 1989 and 1998 Liverpool Hospital has had 6 fetal deaths, of which 5 arrived in the resuscitation room with fetal heart sounds, or CTG evidence of viability.[7] Facilities for rapid caesarean section must be available if fetal deaths are to be avoided. Fetal compromise is present in over 60% of placental abruptions with a live fetus, and an immediate caesarean section is indicated. The overall fetal mortality with placental abruption is 54%.[25] Adequate resuscitation of the mother is absolutely vital. If maternal shock occurs, fetal mortality approaches 80%.

Fetal monitoring should be continued for 24 hours for all patients with a risk factor listed in Box 4. Patients who enter preterm labour and those at risk of developing contractions (ie, gestational age > 35 weeks, victims of assault and pedestrians hit by motor vehicles) should also be monitored for 24 hours.[5] The recommended length of fetal monitoring can been reduced to 6 hours or less in low-risk patients.[5,28]

Maternal plasma bicarbonate levels may be a predictor of outcome. Scorpio et al found that injured mothers with fetuses who survived had a mean plasma bicarbonate level of 20.3 ± 2.2 mEq/L compared with 16.4 ± 3.0 mEq/L in those with fetal loss.[29]

Restoration of both maternal and fetal circulation is the goal of adequate resuscitation. However, there are unusual situations in which exclusive attention to the mother may preclude delivery of a viable baby. Maternal revival after delivery of the fetus has been reported in perimortem circumstances, presumably due to relief of vena cava compression, or more effective cardiopulmonary resuscitation after pressure below the diaphragm is relieved, but this is rare. It is therefore suggested that there is no place for postmortem caesarean section — only perimortem caesarean section. If there is no response to advanced resuscitation within a few minutes, maternal cardiopulmonary resuscitation should be continued, and a caesarean section should be performed.

In a review of 250 years of literature to 1961, Ritter found 120 successful perimortem caesarean sections reported.[30] Strong et al, writing in 1989, reported that about half the perimortem caesarean sections in the literature had produced live infants, but the incidence of neurological sequelae increases with increasing delays to delivery. The long-term survival rate of healthy infants was 15%.[31]

Caesarean section should only be performed in the emergency department when the uterine size exceeds the umbilicus, there is evidence of fetal heart activity (either on

Doppler or M-Mode ultrasound) and the patient has been receiving cardiopulmonary resuscitation for not more than 10 minutes. It is important to consider the possibility of other complications of trauma in pregnancy such as amniotic fluid embolism and fetomaternal haemorrhage (which affects about 30% of pregnant women suffering recent abdominal and/or multiple trauma).[32]

Amniotic fluid embolism is rare, but it is an important cause of disseminated intravascular coagulation and shock.[33] It was first described by Meyer in 1926 and established as a clinical entity by Steiner in 1941.[34] Amniotic fluid embolism is almost always fatal and should be suspected in every instance of the traumatised pregnant patient who develops signs of respiratory distress with or without right heart strain and disseminated intravascular coagulation. Wider application of right heart-blood smear and searching for monoclonal antibodies against fetal mucin may provide a better indication of the prevalence of the problem.

Fetomaternal haemorrhage is the transplacental passage of fetal cells into the maternal circulation and is a unique complication of pregnancy. The reported instance is 8%–30% in traumatised pregnant women, compared with 2%–8% for non-traumatised mothers.[21,35] Anterior placental location and uterine tenderness have been associated with an increased risk of fetomaternal haemorrhage. Complications include rhesus sensitisation in the mother, fetal anaemia, fetal tachycardia and fetal death. The volume of fetal blood lost after trauma can vary between 5–40 mL — this can represent up to 34% of fetal blood volume. As little as 1 mL of rhesus positive blood can sensitise 70% of rhesus negative women.[32,36] Therefore, all rhesus negative mothers who present with a history of abdominal trauma should receive a prophylactic dose of Rh immune globulin. The Kleihauer–Betke test has been used to determine the presence of fetal maternal haemorrhage. It is semi quantitative and may alert the obstetrician to a serious hazard for the fetus – even in Rhesus positive women.

Conclusion

Trauma in pregnancy, although uncommon, requires a consistent approach, with monitoring of all patients for at least 6 hours, and of high-risk patients for 24 hours or longer. Early care should follow EMST/ATLS principles, with early use of FAST in the resuscitation room, followed by a formal ultrasound of the abdomen and fetus.

The patient should be monitored in a labour ward under joint trauma and obstetric care. Detection of fetal distress should prompt immediate caesarean section.

Competing interests

None declared.

References

1. Caldwell E, Sugrue M, Johansson K, et al. South Western Sydney Area Health Service Regional Trauma Registry Report on 5 years, 1995 to 1999. [ISBN 1 875909 88 5]. Sydney: SWSAHS, 2000.
2. Shah K, Simons RK, Holbrook T, et al. Trauma in pregnancy. Maternal and fetal outcomes. *J Trauma* 1998; 45: 83-87.
3. Drost TF, Rosemurgy AS, Sherman HF, et al. Major trauma in pregnant women: maternal/fetal outcome. *J Trauma* 1990; 30: 574-578.
4. Vaizey CJ, Jacobson MJ, Cross FW. Trauma in pregnancy. *Br J Surg* 1994; 81: 1406-1415.
5. Curet MJ, Schermer CR, Demarest GB, et al. Predictors of outcome in trauma during pregnancy: identification of patients who can be monitored for less than 6 hours. *J Trauma* 2000; 49: 18-24; discussion 24-25.
6. Theodorou DA, Velmahos GC, Souter I, et al. Fetal death after trauma in pregnancy. *Am Surg* 2000; 66: 809-812.
7. Sugrue M, Kolkman KA. Trauma during pregnancy. *Aust J Rural Health* 1999; 7: 82-84.
8. Mighty H. Trauma in pregnancy. *Crit Care Clin* 1994; 10: 623-633.
9. Buschbaum HJ. Diagnosis and management of abdominal gunshot wounds during pregnancy. *J Trauma* 1975; 15: 425-431.
10. Sakala EP, Kort DD. Management of stab wounds to the pregnant uterus: a case report and review of the literature. *Obstet Gynecol Surv* 1988; 43: 319-324.
11. Kaloo P, Ludlow J, Dickinson JE, Smith N. Self-inflicted penetrating abdominal injury in pregnancy. *Aust N Z J Obstet Gynaecol* 2000; 40: 468-470.
12. Jacobson M, Mitchell R. Trauma to the pregnant abdomen in pregnancy. *South African J Surg* 1983; 21: 71-73.
13. Marx GF. Shock in the obstetric patient. *Anesthesiology* 1965; 26: 423-434.
14. Lu WH, Kolkman K, Seger M, Sugrue M. An evaluation of trauma team response in a major trauma hospital in 100 patients with predominantly minor injuries. *Aust N Z J Surg* 2000; 70: 329-332.
15. Pape HC, Pohlemann T, Gansslen A, et al. Pelvic fractures in pregnant multiple trauma patients. *J Orthopaedic Trauma* 2000; 14: 238-244.
16. Goodwin H, Holmes JF, Wisner DH. Abdominal ultrasound examination in pregnant blunt trauma patients. *J Trauma* 2001; 50: 689-694.
17. Sugrue M. Dilemmas in the assessment of abdominal trauma. Manual for ultrasound in trauma. [ISBN 1 875909 82 6]. Sydney: SWSAHS, 2000: 32-54.
18. Sugrue M, Seger M, Sloane D, Deane S. A modified combination technique for performing diagnostic peritoneal lavage. *Aust N Z J Surg* 1995; 65: 604-606.
19. Rothenberger DA, Quattlebaum FW, Zabel J. Diagnositic peritoneal lavage for blunt trauma in pregnant women. *Am J Obstet Gynecol* 1977; 129: 478-483.
20. Janjua KJ, Sugrue M, Jones F, et al. Prospective evaluation of early missed injuries and the role of the tertiary trauma survey. *J Trauma* 1998; 44: 1000-1007.
21. Pearlman MD, Tintinelli JE, Lorenz PR. A prospective study of the outcome after trauma during pregnancy. *Am J Obstet Gynecol* 1990; 162: 1502-1510.
22. Esposito TJ, Gens DR, Smith LG, Scorpio R. Evaluation of blunt abdominal trauma occurring during pregnancy. *J Trauma* 1989; 29: 1628-1632.
23. Baerga-Varela Y, Zietlow S, Bannon M, et al. Trauma in pregnancy. *Mayo Clin Proc* 2000; 75: 1243-1248.
24. Hoff WS, D'Amelio LF, Tinkoff GH, et al. Maternal predictors of fetal demise in trauma during pregnancy. *Gynecol Obstet Surg* 1991; 172: 175-180.
25. Rogers FB, Rozycki GS, Osler TM, et al. A multi-institutional study of factors associated with fetal death in injured pregnant patients. *Arch Surg* 1999; 134: 1274-1277.
26. Share JC, Pursley D, Teele RL. Unsuspected hepatic injury in the neonate — diagnosis by ultrasonography. *Pediatr Radiol* 1990; 20: 320-322.
27. Fries MH, Hankins GDV. Motor vehicle accident associated with minimal maternal trauma but subsequent fetal demise. *Ann Emerg Med* 1989; 18: 301-304.
28. Williams JK, McClain L, Rosemurgy AS, Colorado NM. Evaluation of blunt abdominal trauma in the third trimester of pregnancy: maternal and fetal considerations. *Obstet Gynecol* 1990; 75: 33-37.
29. Scorpio RJ, Esposito TJ, Smith LG, Gens DR. Blunt trauma during pregnancy: factors affecting fetal outcome. *J Trauma* 1992; 32: 213-216.
30. Ritter JW. Postmortem cesarean section. *JAMA* 1961; 175: 715-716.
31. Strong TH Jr, Lowe RA. Perimortem cesarean section. *Am J Emerg Med* 1989; 7: 489-494.
32. Rose PG, Strohm MT, Zuspan FP. Fetomaternal haemorrhage following trauma. *Am J Obstet Gynecol* 1985; 153: 844-847.
33. Judich A, Kuriansky J, Engelberg I, et al. Amniotic fluid embolism following blunt abdominal trauma in pregnancy. *Injury* 1998; 29: 475-477.
34. Steiner PE, Lushbaugh CC. Maternal pulmonary embolism by amniotic fluid as a cause of obstetric shock and unexpected deaths in obstetrics. *JAMA* 1941; 117: 1245-1340.
35. Goodwin TM, Breen MT. Pregnancy outcome and fetomaternal hemorrhage after non-catastrophic trauma. *Am J Obstet Gynecol* 1990; 162: 665-671.
36. Mollison PL. Clinical aspects of Rh immunization. *Am J Clin Path* 1973; 60: 287-301.

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