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Guidelines for the Management of a Pregnant Trauma Patient

This clinical practice guideline has been prepared by the Maternal Fetal Medicine Committee, reviewed by the Clinical Practice – Obstetrics, Medico-Legal, and Family Physician Advisory Committees, and approved by Executive and Board of the Society of Obstetricians and Gynaecologists of Canada

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Abstract

Objective: Physical trauma affects 1 in 12 pregnant women and has a major impact on maternal mortality and morbidity and on pregnancy outcome. A multidisciplinary approach is warranted to optimize outcome for both the mother and her fetus. The aim of this document is to provide the obstetric care provider with an evidence-based systematic approach to the pregnant trauma patient.

Outcomes: Significant health and economic outcomes considered in comparing alternative practices.

Evidence: Published literature was retrieved through searches of Medline, CINAHL, and The Cochrane Library from October 2007 to September 2013 using appropriate controlled vocabulary (e.g., pregnancy, Cesarean section, hypotension, domestic violence, shock) and key words (e.g., trauma, perimortem Cesarean, Kleihauer-Betke, supine hypotension, electrical shock). Results were restricted to systematic reviews, randomized control trials/controlled clinical trials, and observational studies published in English between January 1968 and September 2013. Searches were updated on a regular basis and incorporated in the guideline to February 2014.

Grey (unpublished) literature was identified through searching the websites of health technology assessment and health technology-related agencies, clinical practice guideline collections, clinical trial registries, and national and international medical specialty societies.

Values: The quality of evidence in this document was rated using the criteria described in the Report of the Canadian Task Force on Preventive Health Care (Table 1).

Benefits, harms, and costs: This guideline is expected to facilitate optimal and uniform care for pregnancies complicated by trauma.

SUMMARY STATEMENT

Specific traumatic injuries

At this time, there is insufficient evidence to support the practice of disabling air bags for pregnant women. (III)

RECOMMENDATIONS

Primary survey

1. Every female of reproductive age with significant injuries should be considered pregnant until proven otherwise by a definitive pregnancy test or ultrasound scan. (III-C)

Table 1. Key to evidence statements and grading of recommendations, using the ranking of the Canadian Task Force on Preventive Health Care

Quality of evidence assessment*	Classification of recommendations†
I: Evidence obtained from at least one properly randomized controlled trial	A. There is good evidence to recommend the clinical preventive action
II-1: Evidence from well-designed controlled trials without randomization	B. There is fair evidence to recommend the clinical preventive action
II-2: Evidence from well-designed cohort (prospective or retrospective) or case–control studies, preferably from more than one centre or research group	C. The existing evidence is conflicting and does not allow to make a recommendation for or against use of the clinical preventive action; however, other factors may influence decision-making
II-3: Evidence obtained from comparisons between times or places with or without the intervention. Dramatic results in uncontrolled experiments (such as the results of treatment with penicillin in the 1940s) could also be included in this category	D. There is fair evidence to recommend against the clinical preventive action
	E. There is good evidence to recommend against the clinical preventive action
III: Opinions of respected authorities, based on clinical experience, descriptive studies, or reports of expert committees	L. There is insufficient evidence (in quantity or quality) to make a recommendation; however, other factors may influence decision-making

*The quality of evidence reported in here has been adapted from The Evaluation of Evidence criteria described in the Canadian Task Force on Preventive Health Care.[133]

†Recommendations included in these guidelines have been adapted from the Classification of Recommendations criteria described in the Canadian Task Force on Preventive Health Care.[133]

2. A nasogastric tube should be inserted in a semiconscious or unconscious injured pregnant woman to prevent aspiration of acidic gastric content. (III-C)
3. Oxygen supplementation should be given to maintain maternal oxygen saturation > 95% to ensure adequate fetal oxygenation. (II-1B)
4. If needed, a thoracostomy tube should be inserted in an injured pregnant woman 1 or 2 intercostal spaces higher than usual. (III-C)
5. Two large bore (14 to 16 gauge) intravenous lines should be placed in a seriously injured pregnant woman. (III-C)
6. Because of their adverse effect on uteroplacental perfusion, vasopressors in pregnant women should be used only for intractable hypotension that is unresponsive to fluid resuscitation. (II-3B)
7. After mid-pregnancy, the gravid uterus should be moved off the inferior vena cava to increase venous return and cardiac output in the acutely injured pregnant woman. This may be achieved by manual displacement of the uterus or left lateral tilt. Care should be taken to secure the spinal cord when using left lateral tilt. (II-1B)
8. To avoid rhesus D (Rh) alloimmunization in Rh-negative mothers, O-negative blood should be transfused when needed until cross-matched blood becomes available. (I-A)
9. The abdominal portion of military anti-shock trousers should not be inflated on a pregnant woman because this may reduce placental perfusion. (II-3B)

Transfer to health care facility

10. Transfer or transport to a maternity facility (triage of a labour and delivery unit) is advocated when injuries are neither life- nor limb-threatening and the fetus is viable (≥ 23 weeks), and to the emergency room when the fetus is under 23 weeks' gestational age or considered to be non-viable. When the injury is major, the patient should be transferred or transported to the trauma unit or emergency room, regardless of gestational age. (III-B)
11. When the severity of injury is undetermined or when the gestational age is uncertain, the patient should be evaluated in the trauma unit or emergency room to rule out major injuries. (III-C)

Evaluation of a pregnant trauma patient in the emergency room

12. In cases of major trauma, the assessment, stabilization, and care of the pregnant women is the first priority; then, if the fetus is viable (≥ 23 weeks), fetal heart rate auscultation and fetal monitoring can be initiated and an obstetrical consultation obtained as soon as feasible. (II-3B)
13. In pregnant women with a viable fetus (≥ 23 weeks) and suspected uterine contractions, placental abruption, or traumatic uterine rupture, urgent obstetrical consultation is recommended. (II-3B)
14. In cases of vaginal bleeding at or after 23 weeks, speculum or digital vaginal examination should be deferred until placenta previa is excluded by a prior or current ultrasound scan. (III-C)

Adjunctive tests for maternal assessment

15. Radiographic studies indicated for maternal evaluation including abdominal computed tomography should not be deferred or delayed due to concerns regarding fetal exposure to radiation. (II-2B)
16. Use of gadolinium-based contrast agents can be considered when maternal benefit outweighs potential fetal risks. (III-C)
17. In addition to the routine blood tests, a pregnant trauma patient should have a coagulation panel including fibrinogen. (III-C)
18. Focused abdominal sonography for trauma should be considered for detection of intraperitoneal bleeding in pregnant trauma patients. (II-3B)
19. Abdominal computed tomography may be considered as an alternative to diagnostic peritoneal lavage or open lavage when intra-abdominal bleeding is suspected. (III-C)

Fetal assessment

20. All pregnant trauma patients with a viable pregnancy (≥ 23 weeks) should undergo electronic fetal monitoring for at least 4 hours. (II-3B)

21. Pregnant trauma patients (≥ 23 weeks) with adverse factors including uterine tenderness, significant abdominal pain, vaginal bleeding, sustained contractions (> 1/10 min), rupture of the membranes, atypical or abnormal fetal heart rate pattern, high risk mechanism of injury, or serum fibrinogen < 200 mg/dL should be admitted for observation for 24 hours. (III-B)
22. Anti-D immunoglobulin should be given to all rhesus D-negative pregnant trauma patients. (III-B)
23. In Rh-negative pregnant trauma patients, quantification of maternal–fetal hemorrhage by tests such as Kleihauer-Betke should be done to determine the need for additional doses of anti-D immunoglobulin. (III-B)
24. An urgent obstetrical ultrasound scan should be undertaken when the gestational age is undetermined and need for delivery is anticipated. (III-C)
25. All pregnant trauma patients with a viable pregnancy who are admitted for fetal monitoring for greater than 4 hours should have an obstetrical ultrasound prior to discharge from hospital. (III-C)
26. Fetal well-being should be carefully documented in cases involving violence, especially for legal purposes. (III-C)

Obstetrical complications of trauma

27. Management of suspected placental abruption should not be delayed pending confirmation by ultrasonography as ultrasound is not a sensitive tool for its diagnosis. (II-3D)

Specific traumatic injuries

28. Tetanus vaccination is safe in pregnancy and should be given when indicated. (II-3B)
29. Every woman who sustains trauma should be questioned specifically about domestic or intimate partner violence. (II-3B)
30. During prenatal visits, the caregiver should emphasize the importance of wearing seatbelts properly at all times. (II-2B)

Perimortem Caesarean section

31. A Caesarean section should be performed for viable pregnancies (≥ 23 weeks) no later than 4 minutes (when possible) following maternal cardiac arrest to aid with maternal resuscitation and fetal salvage. (III-B)

ABBREVIATIONS

CNS	central nervous system
CT	computerized tomography
DPL	diagnostic peritoneal lavage
ECG	electrocardiogram
EFM	electronic fetal monitoring
ER	emergency room
FAST	focused abdominal sonography for trauma
ICU	intensive care unit
KB	Kleihauer-Betke
L&D	labour and delivery
MAST	military anti-shock trousers
MFH	maternal-fetal hemorrhage
MVC	motor vehicle collision
Rh	rhesus D

INTRODUCTION

Trauma during pregnancy is the leading cause of non-obstetric maternal mortality, with 20% of maternal deaths directly attributable to injuries.[1] Non-lethal injuries occur in 1 in every 12 pregnant women and are most commonly the result of an MVC or of domestic or intimate partner violence.[1–3] Other common causes of trauma in a pregnant patient are penetrating injuries and falls.[4–6] Health Canada reported maternal mortality as 6.1 per 100 000 live births during 1997–2000.[7] During that period 15 maternal deaths (an incidence of 1.5/100 000) were attributed to MVC. There was no other single diagnosis (pulmonary embolism, preeclampsia, hemorrhage, etc.) with such a high mortality rate. A Swedish national population-based study (1991–2001) reported an MVC incidence of 207/100 000 pregnancies that was associated with a maternal mortality of 1.4 per 100 000 pregnancies and a perinatal mortality of 3.7 per 100 000 pregnancies (an odds ratio of 3.55 compared with the background risk).[8] There was no significant difference in fatal injury risk among pregnant and non-pregnant women involved in an MVC.[8] A report by the National Trauma Data Bank (2001–2005) indicated that trauma-related mortality among pregnant women is lower than that among non-pregnant women.[9] This difference has been attributed to protective hormonal and physiologic effects of pregnancy as well as a higher likelihood of hospital admission of pregnant versus non-pregnant trauma victims.[9,10]

The management of a pregnant trauma patient warrants consideration of several issues specific to pregnancy such as alterations in maternal physiology and anatomy, exposure to radiation and other possible teratogens, the need to assess fetal well-being, and conditions that are unique to pregnancy and are related to trauma (Rh isoimmunization, placental abruption, and preterm labour). Optimization of outcome in severe trauma cases mandates a multidisciplinary team approach involving trauma surgeons, emergency medicine physicians, obstetricians, neonatologists, nursing staff, and technicians. The obstetrician (or other obstetric care provider) plays a major role in determining gestational age, optimizing uteroplacental perfusion, assessing fetal well-being, providing information about the risks of radiation exposure and use of medications, and deciding upon and executing an emergency Caesarean section.

A systematic, evidence-based approach to the management of maternal trauma is hereby provided to assist and guide physicians involved in such cases, either as primary caregivers or consultants.

PRIMARY SURVEY

Seriously injured trauma victims are occasionally unable to communicate with the primary caregiver. In addition, some women may be unaware of their pregnancy status. One study showed that 3% of women admitted to a trauma unit were pregnant, and of these 11% were incidental pregnancies.[11] Therefore, it is recommended that every injured female of childbearing years should be considered pregnant until proven otherwise. Following admission of the patient for further care in a health care facility, a pregnancy test should be performed.[12] The confirmation of pregnancy may have a major impact on future decisions regarding diagnostic imaging, use of medications, and other treatment modalities.

As with non-pregnant women, the initial assessment of an acutely injured pregnant woman should include securing her airway, ensuring breathing, and maintaining adequate circulation. The most important lifesaving primary interventions might include, for example, intubation and controlling severe external hemorrhage.

Airway

The pregnant patient has a greater risk for airway management problems and difficult intubation than the non-pregnant patient.[13] Weight gain, respiratory tract mucosal edema, decreased functional residual capacity, reduced respiratory system compliance, increased airway resistance, and increased oxygen requirements are pregnancy-induced changes that place the injured pregnant woman at risk for failure to maintain a patent airway and secured ventilation.[14] An early intubation should be considered in whenever airway problems are anticipated.

Injured pregnant women with an unsecured airway are at increased risk for aspiration of gastric contents. Gastric emptying is delayed in pregnancy and pregnant women should be considered to have a full stomach for up to 24 hours after their last meal. Intubation is more difficult in pregnant patients, with failed intubations being 8 times more likely.[15] A smaller size of endotracheal tube is recommended.[15] Cricoid pressure can be considered during intubation to decrease the risk of regurgitation of gastric contents into the pharynx and for manipulation of laryngoscopic view.[15,16] However, adjustment of pressure or early release may be necessary if the view is poor. In addition, early placement of a nasogastric tube is warranted in an unconscious or semiconscious pregnant patient to avoid aspiration in light of decreased gastric motility, compression of the upper gastrointestinal tract, elevated gastric acid, decreased pH, and relaxation of the lower esophageal sphincter.[17]

Breathing

Marked increases in basal oxygen consumption and extreme sensitivity of the fetus to maternal hypoxia mandate supplemental oxygen by a nasal cannula, mask, or endotracheal tube to all pregnant trauma patients to maintain oxygen saturation above 95%.

Taking into account the displacement of the diaphragm during pregnancy, it may be advisable to insert a thoracostomy tube, when indicated, one to 2 intercostal spaces higher than usual.[18]

Circulation

Administration of fluids and blood products during resuscitation should proceed according to standard trauma protocols.[19] Nevertheless, some modifications should be made in the pregnant trauma victim.

Insertion of 2 large bore needles (14–16 gauge) is recommended for all seriously injured trauma patients to facilitate initial rapid crystalloid infusion, intravascular volume expansion, and possible further blood transfusion as required. The uteroplacental vasculature is highly responsive to vasopressors, and their administration may decrease placental perfusion. In cases of maternal hypotension vasopressors should be avoided unless the patient is unresponsive to replenishment of intravascular volume by fluid administration.[20] Bicarbonate should be used with caution, because rapid correction of maternal acidosis can reduce the compensatory hyperventilation.[21] To further facilitate the evaluation of maternal hypovolemia, the pregnant trauma patient should be undressed and a thorough examination for sources of blood loss should be undertaken.

Care must be taken to avoid supine hypotension in the pregnant trauma patient after mid-pregnancy. Compression of the vena cava by the uterus can cause up to 30% reduction in cardiac output.[22] The displacement of the uterus off of the inferior vena cava and abdominal aorta enhances maternal venous return and cardiac output, and consequently improves uterine perfusion.[19,23] This can be achieved either by placing the patient in the left lateral position or by manual displacement of the uterus while the injured patient is secured in the supine position. The latter may allow more effective chest compressions while cardio-pulmonary resuscitation is in progress.[24] A third option is to use a backboard for lateral tilt with secured spine in suspected spinal injuries. Fetal risks from maternal defibrillation are small, especially if all fetal monitors have been removed.[25]

In the setting of acute blood loss necessitating immediate administration of blood products in a pregnant trauma

patient, O-negative blood should be transfused in order to avoid Rh sensitization in Rh-negative women until type-specific or cross-matched donor blood becomes available.

Inflation of the abdominal portion of the MAST is contraindicated during pregnancy as it may lead to reduced placental perfusion and increased cardiac workload.[26]

Recommendations

1. Every female of reproductive age with significant injuries should be considered pregnant until proven otherwise by a definitive pregnancy test or ultrasound scan. (III-C)
2. A nasogastric tube should be inserted in a semiconscious or unconscious injured pregnant woman to prevent aspiration of acidic gastric content. (III-C)
3. Oxygen supplementation should be given to maintain maternal oxygen saturation > 95% to ensure adequate fetal oxygenation. (II-1B)
4. If needed, a thoracostomy tube should be inserted in an injured pregnant woman 1 or 2 intercostal spaces higher than usual. (III-C)
5. Two large bore (14 to 16 gauge) intravenous lines should be placed in a seriously injured pregnant woman. (III-C)
6. Because of their adverse effect on uteroplacental perfusion, vasopressors in pregnant women should be used only for intractable hypotension that is unresponsive to fluid resuscitation. (II-3B)
7. After mid-pregnancy, the gravid uterus should be moved off the inferior vena cava to increase venous return and cardiac output in the acutely injured pregnant woman. This may be achieved by manual displacement of the uterus or left lateral tilt. Care should be taken to secure the spinal cord when using left lateral tilt. (II-1B)
8. To avoid rhesus D (Rh) alloimmunization in Rh-negative mothers, O-negative blood should be transfused when needed until cross-matched blood becomes available. (I-A)
9. The abdominal portion of military anti-shock trousers should not be inflated on a pregnant woman because this may reduce placental perfusion. (II-3B)

TRANSFER TO HEALTH CARE FACILITY

Following successful initial maternal stabilization, the primary care provider should organize further appropriate referral, consultation, and transfer of care as required. The dilemma is not only whether and how to transfer patient care between different health facilities, but also where further care should be provided: in the trauma unit, ER, or community-designated emergency care facility/personnel unit, in an ICU, or in the maternity/L&D unit or community-designated maternity facility/personnel unit. Although most injuries are not categorized as life threatening, they may still be extensive or mandate immediate intervention to prevent long-term consequences for the mother.

Factors that should be taken into consideration are severity of the injuries and gestational age. Maternal health should always take priority over interventions for the fetus. When major maternal trauma is evident or suspected, the patient should be transferred without delay to the trauma unit or ER. The same applies for women with pregnancies of under 23 weeks' gestation, when the fetus is considered non-viable and serious obstetric complications are uncommon. Women over 23 weeks' gestation without life- or limb-threatening injuries should be transported to a maternity or L&D unit as soon as possible. However, the diagnosis of pregnancy is not always certain or obvious. Many seriously injured trauma victims cannot communicate, and some are unaware of their pregnancy status. Gestational age may be unobtainable or uncertain, complicating the process of decision making. The primary care provider should try to assess the gestational age by verbal communication with the patient or her companion or through documentation found in her possession. Fundal height may give a rough estimate of gestational age in most cases of a singleton gestation. Occasionally, injury-related distention of the abdomen may interfere with the estimation of fundal height.

Multiple systems for scoring the severity of trauma have been proposed in the literature,[27] but most of them are cumbersome and are not applicable for on-scene decision making. Severity assessment scoring systems frequently used in trauma and intensive care patients to predict outcome are often not useful in pregnant women admitted to a general ICU.[28] The standard Injury Severity Score assessment is also not accurate in predicting placental abruption and fetal demise. Buchsbaum described simple and applicable criteria that essentially distinguish between major maternal injuries that require further assessment in a trauma centre and minor injuries for which obstetrical surveillance takes precedence.[29] Buchsbaum used criteria such as hematuria, suspected internal bleeding, loss of conscious, and fractures to delineate major trauma. We suggest that these simple parameters should be considered along with common sense when deciding upon patient transfer and transport arrangements for a pregnant woman after 23 weeks' gestation.

Recommendations

10. Transfer or transport to a maternity facility (triage of a labour and delivery unit) is advocated when injuries are neither life- nor limb-threatening and the fetus is viable (≥ 23 weeks), and to the emergency room when the fetus is under 23 weeks' gestational age or considered to be non-viable. When the injury is major, the patient should be transferred or transported to the trauma unit or emergency room, regardless of gestational age. (III-B)
11. When the severity of injury is undetermined or when the gestational age is uncertain, the patient should be evaluated in the trauma unit or emergency room to rule out major injuries. (III-C)

EVALUATION OF A PREGNANT TRAUMA PATIENT IN THE ER

Assessment of a pregnant trauma patient in the ER may require the involvement of a multidisciplinary team that may include an emergency physician or trauma specialist (or the designated emergency care provider), an obstetrician (or obstetrical care provider), a neonatologist, an anaesthetist, and skilled nursing staff. The pregnant patient should be fully assessed, as is a non-pregnant patient, with a thorough history, examination, laboratory tests, imaging studies, and invasive diagnostic procedures as indicated. In addition, special attention should be given to fetal evaluation when gestational age is ≥ 23 weeks and to trauma complications that are unique to pregnancy such as placental abruption. Communication between health care providers can be facilitated by incorporating the emergency triage protocol in the management of pregnancy trauma patients.[30]

History

As in the non-pregnant trauma patient, a thorough history is of utmost importance to delineate the mechanism of injury and possible concealed damage in a pregnant patient. The caregiver should also obtain information about past obstetrical history (e.g., scarred uterus, previous obstetrical complications) and the course of the current pregnancy. Certain pregnancy complications will affect the management of trauma-related injuries. For example, patients with preeclampsia have reduced intravascular volume and are extremely sensitive to hypovolemia and anemia. These patients may also have compromised renal function on the one hand and increased capillary permeability with proneness to pulmonary edema on the other. Awareness of these factors may lead to modification of fluid management with regard to the method and rate of volume replacement and the means of monitoring intravascular volume and cardiac output.

The history should also include inquiries into specific complications of trauma in pregnancy: leakage of fluid, vaginal bleeding, abdominal pain or cramping, intensity and frequency of contractions, and maternal perception of fetal movements.

Physical Examination

The physical examination of pregnant trauma patients is similar to that of non-pregnant patients with modifications for pregnancy-related complications. We endorse the recommendations proposed by the Advanced Trauma Life Support Course of the American College of Surgeons' Committee on Trauma.[19]

All body parts of the pregnant trauma patient should be exposed and thoroughly examined. In recording vital signs it is helpful to keep in mind that the heart rate increases by 15% during pregnancy. Tachycardia and hypotension, typical of hypovolemic shock, may appear late in the pregnant trauma patient because of her increased blood volume.[31] During pregnancy, maternal vital signs and perfusion may be preserved at the expense of uteroplacental perfusion, delaying the occurrence of signs of hypovolemic shock.[32] Not uncommonly, noticeable alterations in vital signs occur only after significant blood loss that may have already diminished uteroplacental perfusion. In these instances, an atypical or abnormal fetal heart rate pattern, in addition to indicating impending fetal hypoxemic injury or even death, may be the first indicator of significant maternal hypovolemia due to hemorrhage.[32–34] Therefore, in a pregnant patient ≥ 23 weeks' gestation, fetal heart rate monitoring should be initiated as soon as possible. This may require having staff from the maternity or L&D unit visit the unit where the pregnant woman is receiving care for her injuries. For those < 23 weeks' gestation, a brief assessment of fetal viability is adequate. Continuous monitoring of oxygen saturation is advised since maternal desaturation may compromise oxygenation of the fetus. Oxygen supplementation should be given to increase oxygen saturation.

Special attention should be paid to the abdomen since serious injuries may involve the gravid uterus as well as other abdominal organs. The contour of the abdomen should be carefully inspected for abnormal distension as a sign of intra-abdominal hemorrhage or perforation of hollow viscus. Meticulous documentation of the location of entrance and exit wounds of penetrating trauma is of paramount importance. The uterus and its contents usually cushion the impact of penetrating trauma; therefore, in women

after mid-pregnancy mortality and incidence of visceral injury with penetrating abdominal trauma are substantially lower than in the general population.[35] However, injuries below the fourth intercostal space anteriorly, or the tip of the scapula posteriorly, should be carefully evaluated for potential thoraco-abdominal penetrating injuries. Risk factors associated with maternal death include bruising injuries to the abdomen, pelvis, or lower back, pelvic fractures, intra-abdominal injuries, and penetrating trauma.[34,36]

Clinical signs of peritoneal irritation are less evident in the pregnant woman; therefore, in cases of suspected abdominal injury, physical examination is less informative in ruling out major organ damage and further investigations should be conducted.[37] The uterus should be assessed for fundal height, shape, hypertonus, and tenderness. Tenderness over the uterus is an important sign suggestive of abruption of the placenta. Irregularities on the abdomen may represent fetal body parts in cases of traumatic uterine rupture. In these cases, rapid response of the medical team can significantly reduce maternal and fetal risks, and urgent obstetrical consultation is recommended.[33,38,39] In some communities, the consultant who can perform a Caesarean and other requisite surgical procedures may be a family physician or a surgeon.

Vaginal examination should be performed for cervical dilatation, effacement, fetal presentation, and station. However, in cases of vaginal bleeding after 23 weeks, speculum or digital vaginal examination should be deferred until placenta previa is excluded by an ultrasound scan. A speculum examination should be performed to assess for vaginal bleeding, pooling of amniotic fluid, cervical dilatation, vaginal or cervical lacerations, and expulsion of gestational tissue.

Recommendations

12. In cases of major trauma, the assessment, stabilization, and care of the pregnant women is the first priority; then, if the fetus is viable (≥ 23 weeks), fetal heart rate auscultation and fetal monitoring can be initiated and an obstetrical consultation obtained as soon as feasible. (II-3B)
13. In pregnant women with a viable fetus (≥ 23 weeks) and suspected uterine contractions, placental abruption, or traumatic uterine rupture, urgent obstetrical consultation is recommended. (II-3B)
14. In cases of vaginal bleeding at or after 23 weeks, speculum or digital vaginal examination should be deferred until placenta previa is excluded by a prior or current ultrasound scan. (III-C)

Table 2. Estimated fetal radiation doses during some common radio-diagnostic procedures

Examination	Fetal dose (mrad)
X-ray	
Upper gastrointestinal series	100
Cholecystography	100
Lumbar spine radiography	400
Pelvic radiography	200
Hip and femur radiography	300
Retrograde pyelography	600
Abdominal radiography	250
Lumbar spine,	
Anteroposterior	750
Lateral	91
Oblique	100
Barium enema	1000
Intravenous pyelogram	480
Computed tomography	
Head	0
Chest	16
Abdomen	3000

(Adapted from Ratnapalan S, Bona N, Koren G; Motherisk Team. Ionizing radiation during pregnancy. Can Fam Physician. 2003 Jul;49:873–4. By permission of Canadian Family Physician.)

mrad: milli-rad (radiation absorbed dose)

ADJUNCTIVE TESTS FOR MATERNAL ASSESSMENT

Radiographic Studies

Plain radiographs of the cervical spine, chest, and pelvis are first line radiological studies.[19] Clinicians are often reluctant to order imaging studies for pregnant patients out of concern about fetal exposure to ionizing radiation. Patients' attitudes may also reflect anxieties that are disproportionate to the actual risks. Ionizing radiation has the highest teratogenic potential during the period of organogenesis (5–10 weeks), with an increased risk of miscarriage before this period.[40–42] After 10 weeks, radiation is more likely to produce growth restriction or CNS effects than teratogenenic changes.[40,43] Fetal exposure from the radiological examinations that are routinely used in the evaluation of pregnant trauma patients presents a very low risk to the developing fetus (Table 2).[40,44,45] Radiation exposure with a cumulative dose of > 5–10 rads (50–100 mGy) is associated with an increased risk of fetal malformation or CNS effects, limited usually to a gestational age < 18 weeks.[40,42,46–48] Concerns about fetal exposure to radiation should not preclude or delay any indicated radiological evaluation. CT studies are associated

with increased fetal radiation exposure depending on the body part being scanned, the gestational age, the number and thickness of slices, and the equipment used. With abdominal CT during the third trimester the fetal exposure is around 3.5 rads, which is still under the threshold for fetal damage.[49] Use of gadolinium-based contrast agents has shown fetal toxicity in animal studies, though no adverse effects have been reported in human fetuses.[50] Their use can be considered when the maternal benefit outweighs potential fetal risks.

The carcinogenic effects of ionizing radiation exposure are still in dispute. Some studies have suggested an increased risk with exposure to even a low dose of ionizing radiation in utero, especially before 8 weeks.[48,51–53] However, the lifetime cancer risk from prenatal exposure is considered to be similar to that from exposure during childhood.[48] Further, at an exposure level of < 5 rad, the additional lifetime risk was < 2% (< 0.6% during childhood), over and above the background lifetime risk of around 40%.[46] Other studies, including a large Ontario-based cohort, could not confirm an increased risk.[54,55] Therefore, if there is any carcinogenic potential of ionizing radiation exposure at levels usually used in diagnostic procedure, it is thought to be quite low. However, careful consideration of alternative forms of evaluation, accurate completion of ionizing studies to avoid duplication, and limitation of the number of CT cuts or area studied may be beneficial in limiting fetal exposure to radiation.

Laboratory Tests

In all trauma patients, laboratory tests are often ordered by protocol, but in pregnant patients the clinician should be aware of alterations in the normal range of a few laboratory values. The white blood count is usually elevated and counts up to 20×10^9/L may represent the physiologic response to pregnancy. Leukocytosis should be correlated with clinical findings, other lab tests, and imaging studies to confirm the suspicion of infection or inflammation. Fibrinogen values are often more than 4 g/L during pregnancy,[56] therefore the normal values of 2.5 to 3 g/L for a non-pregnant patient may actually signify mild hypofibrinogenemia, and levels below 2 g/L may indicate disseminated intravascular coagulation, a frequent comorbidity of significant placental abruption.[57] D-dimer measurement is a marker for venous thromboembolism. However, during pregnancy, the D-dimer is often positive and therefore is of little value in the diagnosis or exclusion of venous thromboembolism. Normal range for the partial pressure of CO_2 is decreased during pregnancy to 27 to 32 mmHg, thus normal non-pregnant values of 40 mmHg may result from mild hypoventilation. Serum creatinine levels are decreased during pregnancy to 50 to 60 μmol/L, and even a value as low as 90 μmol/L may be abnormal. Alkaline phosphatase is secreted by the placenta, thus levels that are twice the upper limit for non-pregnant patients are within the normal range during pregnancy (up to 140 IU/L).[58,59] In addition to the routine laboratory studies for trauma evaluation, it is advisable to order a coagulation profile including fibrinogen.[57]

Additional Investigations

Abdominal ultrasound

FAST is a useful aid for the detection of intraperitoneal fluid in pregnant trauma patients with suspected intra-abdominal injury. The sensitivity of FAST in detecting intraperitoneal fluid in pregnant blunt trauma patients was 83% in a study that reviewed 127 pregnant trauma patients.[60] This rate is similar to that in a previously published study of non-pregnant trauma patients.[61,62] FAST is an easy and rapid modality that has the added advantage of avoiding fetal exposure to ionizing radiation, it should therefore be part of the secondary survey in pregnant patients with major trauma.

Peritoneal lavage and laparotomy

DPL is a very rapid and sensitive test with sensitivity of 96% to 100% for detection of traumatic intra-abdominal injury.[63] The main disadvantages of this low cost, easily interpretable test are that it does not provide information about specific organ damage, and abdominal injuries that can be managed conservatively following CT would require operative intervention based upon DPL. For these reasons, CT is the most widely used screening modality for blunt abdominal trauma. CT identifies specific organ injury, evaluates the retroperitoneum as well and is less invasive than DPL. Concerns over fetal exposure to radiation during pregnancy may lead to a more frequent use of DPL. The open lavage technique is preferable over a blind needle insertion in the pregnant patient in order to minimize uterine injury.[64] When significant abdominal blood is detected, an exploratory laparotomy with a midline incision should be performed.

Recommendations

15. Radiographic studies indicated for maternal evaluation including abdominal computed tomography should not be deferred or delayed due to concerns regarding fetal exposure to radiation. (II-2B)
16. Use of gadolinium-based contrast agents can be considered when maternal benefit outweighs potential fetal risks. (III-C)
17. In addition to the routine blood tests, a pregnant trauma patient should have a coagulation panel including fibrinogen. (III-C)

18. Focused abdominal sonography for trauma should be considered for detection of intraperitoneal bleeding in pregnant trauma patients. (II-3B)
19. Abdominal computed tomography may be considered as an alternative to diagnostic peritoneal lavage or open lavage when intra-abdominal bleeding is suspected. (III-C)

FETAL ASSESSMENT

Assessment of a viable fetus (≥ 23 weeks gestational age) should be initiated immediately following, or in parallel with the physical examination of the stabilized mother since it has been shown that most placental abruptions occur shortly after the insult.[33] The objectives are:

- identification of impending hypoxemic fetal injury or death as a result of uteroplacental compromise or placental abruption,
- detection of trauma-related complications of pregnancy such as placental abruption, preterm delivery and spontaneous rupture of the membranes,
- evaluation of the degree of maternal–fetal hemorrhage and resultant fetal anemia,
- delineation of fetal injuries, and
- identification of compensated maternal hypovolemia first manifested by decreased placental perfusion.

Knowledge of the estimated gestational age is essential for appropriate interpretation of tests for fetal viability and well-being. Along with clinical examination of fundal height and palpation for uterine contractions and tone, in absence of certainty regarding the gestational age, an ultrasound examination should be undertaken. Electronic monitoring of the fetal heart rate should be initiated on viable fetuses (≥ 23 weeks) as soon as possible. With a confirmed pre-viable fetus, it may be sufficient to demonstrate the presence of fetal cardiac activity.

Monitoring of Fetal Heart Rate and Uterine Activity

EFM allows assessment of fetal well-being and uterine activity, with abnormality of either being predictive of potential obstetrical complications such as placental abruption, fetal hypoxic injury or fetal death. Rothenberger et al reported fetal loss in 61% of cases with major maternal injuries and 27% with minor injuries, with no effect on pregnancy outcome following insignificant maternal injuries.[39] Hospital-based studies have suggested a 5% to 19% risk of fetal death as opposed to a 1.3% risk in population-based studies. This difference may result from the fact that more serious injuries are more likely to be assessed in a hospital.[8,65–67] Fetal death may be an expected consequence of maternal death.[33,38] However, a high Injury Severity Score, serious abdominal injury and hemorrhagic shock all increase the risk of fetal loss.[33,38] Maternal trauma resulting in hypovolemic shock can reduce uterine perfusion, a direct function of systemic blood pressure.[68] This can be further compounded by visceral vasoconstriction. Placental abruption can further reduce transplacental oxygenation. A combination of these factors can lead to fetal hypoxemic injury. Compromised fetal perfusion and oxygenation usually presents with abnormalities in the fetal heart rate pattern. An abnormality in the fetal heart rate pattern may also be the first sign of maternal hemodynamic compromise.[67]

Occasional uterine contractions are the most common finding with trauma during pregnancy, occurring in 40% of cases,[69] and resolving in 90% of cases with no adverse fetal outcome.[70] The intensity and frequency of contractions are predictive of complications such as traumatic placental abruption and preterm labour. Elevated basal uterine tone also raises the suspicions for placental abruption.

Abnormal EFM tracings following trauma are not reliable in predicting adverse obstetrical outcome (sensitivity of 62% and specificity of 49%).[69,71] However, the combination of a normal tracing and physical examination has a negative predictive value of 100% in excluding major adverse fetal outcome.[33,69,72] Atypical or abnormal fetal heart rate patterns such as decelerations, bradycardia, tachycardia or loss of variability mandate further testing, in utero resuscitation with supplemental oxygen, IV fluids and left lateral decubitus positioning or delivery, depending on the severity of the abnormal pattern, the presumed cause and gestational age. About 2.4% to 7.2% of maternal trauma patients require a Caesarean delivery shortly after trauma.[34,38] Need for a Caesarean section shortly after trauma is also a risk factor for maternal death.[34]

The duration of fetal monitoring following maternal trauma remains disputed. For many years it has been suggested that fetal monitoring should continue for at least 24 hours following the insult[33,64,73,74] and some even suggested a 48-hour period of close fetal monitoring.[75] In a prospective study of pregnant trauma patients that had EFM for a minimum of 4 hours, the majority demonstrated uterine activity during that period.[70] Contractions then abated in most patients. Patients were discharged home if contractions ceased or were less frequent than once every 15 minutes. These patients had pregnancy outcomes similar to that in an uninjured control group. The sensitivity of predicting placental

abruption by the frequency of uterine activity in the first 4 hours after trauma was 100%. The study suggested that 4 hours of monitoring was a sensitive method of predicting immediate post-traumatic adverse obstetrical outcomes. Another retrospective study of 271 pregnant patients, suggested monitoring for at least 24 hours only for a selected group of patients at high risk for fetal demise, preterm labour, and placental abruption.[76] This high risk group consisted of patients involved in motorcycle, pedestrian or high velocity collisions, those ejected from motor vehicles and patients demonstrating maternal tachycardia, abnormal fetal heart rate pattern, and high injury severity scores. In a study of 317 patients with minor trauma (48% with falls), 14% had frequent contractions requiring observation for 24 hours.[77] Delivery information was available in 80%. Only one case of placental abruption occurred, remote from the trauma. There were no other trauma-related adverse events.

We suggest hospitalization and intermittent fetal heart rate and uterine activity monitoring by EFM for 24 hours for patients with

- uterine tenderness,
- significant abdominal pain,
- vaginal bleeding,
- a contraction frequency of more than once per 10 minutes during a monitoring period of 4 hours,
- rupture of the membranes,
- atypical or abnormal fetal heart rate pattern (fetal tachycardia, bradycardia or decelerations),
- high risk mechanism of injury (motorcycle, pedestrian, high speed crash), or
- serum fibrinogen < 200 mg/dL
- Monitoring for 4 hours is sufficient to rule out major trauma-related complications in low risk patients without the above mentioned risk factors.[69,72,78]

Prevention of Rh Alloimmunization and Evaluation of Maternal-fetal Hemorrhage

Traumatic placental injury can result in MFH. MFH occurs in 10% to 30% of pregnant trauma patients.[79] Massive MFH is a rare complication of trauma and is usually clinically evident, with fetal demise, abnormal fetal heart rate pattern (bradycardia or recurrent decelerations), or abrupt fetal anemia and cardiac failure. The vast majority of post-traumatic transplacental hemorrhages are smaller and subclinical. The quantification of the amount of fetal blood cells in the maternal circulation enables the obstetric care provider to roughly estimate the degree of transplacental hemorrhage. This may be important in prevention of Rh alloimmunization in Rh-negative mothers. It has also been suggested that a larger MFH may be predictive of other adverse obstetrical outcomes.[80]

The Rh antigen is well developed by 6 weeks gestation[81] and as little as 0.001 mL of fetal blood can cause sensitization of the Rh-negative mother. Even minor trauma in pregnancy may cause sensitizing MFH. Several studies have demonstrated reduced Rh alloimmunization after routine administration of anti-D immune globulin G (IgG) to Rh-negative mothers.[81–83] Therefore, anti-D IgG should be given to all Rh-negative pregnant trauma patients.[84] A single dose of 300 mg, administered within 72 hours of injury, provides protection against sensitization for up to 30 mL of fetal blood in the maternal circulation.[84–86] The feto-placental blood volume is estimated to be 120 mL/kg of fetal weight. In most cases of traumatic maternal–fetal hemorrhage, the estimated volume of fetal blood in the maternal circulation is less than 15 mL and in more than 90% of cases it is less than 30 mL.[70,78] Therefore, the vast majority of Rh-negative patients are protected by one ampule.

The KB test has been used to quantify MFH, so that Rh-negative women could receive appropriate Rh immune prophylaxis. If the KB test indicates transplacental hemorrhage in excess of 30 mL fetal blood, additional doses of anti-D IgG may be required. According to the SOGC recommendations for prevention of Rh alloimmunization,[84] KB test may be considered following events potentially associated with placental trauma and disruption of the maternal–fetal interface (e.g., placental abruption, blunt trauma to the abdomen).

A novel approach for detecting MFH, using flow cytometry as a simpler, more objective, and more precise alternative to the KB method has been advocated.[87,88] Another study has shown that both manual KB test and flow cytometry have good sensitivity in detecting and quantifying fetal red cells.[89] Taking into consideration that flow cytometry is not available in most medical facilities and its added value is still being investigated, we cannot recommend its routine use at this time.

The universal use of KB testing for all pregnant trauma patients, regardless of their Rh status had been advocated by some,[80,90] hypothesizing that the magnitude of MFH reflects severity of injury and therefore would be predictive of trauma-related obstetrical complication such as preterm labour. In one study of maternal trauma, of the 46 patients with a positive KB test, 44 had contractions (of which 25 had preterm labour), and of the 25 patients with a negative KB test, none

had contractions or preterm labour.[80] No information was available in this study regarding the incidence of preterm delivery. The authors concluded that KB test accurately predicted the risk of preterm labour, and clinical examination did not. However, it can be argued that since all women with contractions had a positive test, and those without contractions did not, presence of uterine contractions can be used as a surrogate marker for occurrence of MFH. Therefore the utility of KB test in rhesus-positive women is not clear. Another review suggested that KB test should be performed in all maternal trauma cases, although the basis for this recommendation for rhesus-positive women was not apparent.[90] Others have suggested the KB test is only useful in Rh-negative women.[69,91] A study comparing incidence of a positive KB test in women with history of trauma and that in a low risk population found no significant difference (2.6% vs. 5.1%, respectively).[92] Based on the evidence, we suggest that KB testing should be done in all rhesus-negative pregnant trauma patients. Though EFM is more likely to be clinically useful in rhesus-positive women, KB test can be considered as an optional test to determine the need for prolonged monitoring. Given the high incidence of a false-positive KB test, in rhesus-positive women, assessment of MFH by flow cytometry could be a useful adjunct in differentiating true positive KB tests from the false-positive ones.

The Role of Ultrasound

Ultrasonography is a rapid, non-invasive, valuable tool in the assessment of pregnant trauma patients and it does not require transport of the patient from the trauma unit. An obstetrical ultrasound scan should be done urgently in cases where the gestational age cannot be determined with certainty and need for delivery is anticipated based on an atypical or abnormal fetal heart rate pattern or suspicion of placental abruption. However, it is not sensitive in diagnosing placental abruption[70,72] Between 50% and 80% of traumatic abruptions will be missed and those detected by sonography are usually the clinically apparent ones, which pose no diagnostic challenge.[70,78] The role of the biophysical profile in predicting adverse obstetrical outcome following trauma is yet to be studied.[93] However, in the setting of trauma, EFM is a more sensitive tool not only to rule out a placental abruption but also for assessment of fetal well-being as compared to ultrasound.[70,74,78] Nevertheless, ultrasound is an important adjunctive to the physical examination and fetal assessment tests. Ultrasonography may assist in:

- determination of gestational age
- demonstration of fetal cardiac rate and rhythm
- placental localization and exclusion of placenta previa
- assessment of amniotic fluid volume
- cervical length assessment
- fetal well-being (biophysical profile)
- detection of fetal anemia by peak systolic flow velocity in the middle cerebral artery
- delineation of possible fetal injury, and
- confirmation of fetal demise.

Therefore, an obstetrical ultrasound examination is recommended in all cases of significant maternal trauma that are admitted for monitoring for more than 4 hours. However, ultrasound should only be used to complement EFM, the latter being more sensitive in predicting adverse outcomes such as placental abruption or fetal hypoxic injury.[69–72] In cases where severe MFH occurred, generally there is no time for diagnostic tests such as KB test or middle cerebral artery Doppler. Fetal heart tracing is usually abnormal, and prompt delivery is recommended. Ultrasound needs to be done on an urgent basis only in cases where fetal viability is in question, in all other cases, it can be undertaken as a non-urgent follow-up examination prior to discharge of the patient from the hospital. A reassuring biophysical profile should never be used as a surrogate for EFM. After discharge from hospital, a follow-up obstetric ultrasound examination in 2 weeks should be considered for all patients who needed hospital admission for maternal or fetal factors (regardless of gestational age), this is to document normalcy after the traumatic event, especially of fetal intracranial anatomy and to assess fetal growth in the interval.[94]

Recommendations

20. All pregnant trauma patients with a viable pregnancy (≥ 23 weeks) should undergo electronic fetal monitoring for at least 4 hours. (II-3B)
21. Pregnant trauma patients (≥ 23 weeks) with adverse factors including uterine tenderness, significant abdominal pain, vaginal bleeding, sustained contractions (> 1/10 min), rupture of the membranes, atypical or abnormal fetal heart rate pattern, high risk mechanism of injury, or serum fibrinogen < 200 mg/dL should be admitted for observation for 24 hours. (III-B)
22. Anti-D immunoglobulin should be given to all rhesus D-negative pregnant trauma patients. (III-B)
23. In Rh-negative pregnant trauma patients, quantification of maternal–fetal hemorrhage by tests such as Kleihauer-Betke should be done to determine the need for additional doses of anti-D immunoglobulin. (III-B)

24. An urgent obstetrical ultrasound scan should be undertaken when the gestational age is undetermined and need for delivery is anticipated. (III-C)
25. All pregnant trauma patients with a viable pregnancy who are admitted for fetal monitoring for greater than 4 hours should have an obstetrical ultrasound prior to discharge from hospital. (III-C)
26. It is important to have careful documentation of fetal well-being in cases involving violence, especially for legal purposes. (III-C)

OBSTETRICAL COMPLICATIONS OF TRAUMA

Placental Abruption

Abruption of the placenta is a major complication of maternal trauma, occurring in 5-50% of cases, depending on the severity of injury.[70,78] It is the most common cause of fetal death in cases of blunt trauma. Resulting from the difference in physical properties of the relatively inelastic placental tissue versus the elastic myometrium, significant abruption of the highly vascular uteroplacental interface can mediate rapid maternal and in some cases fetal exsanguination. Most abruptions occur within 2 to 6 hours after the injury, and almost all of them with 24 hours of injury.[33,95] Abruption may follow even minor trauma and requires high index of suspicion to detect. The diagnosis of abruption is based on clinical impression, laboratory tests and fetal evaluation. Typical findings include abdominal pain, uterine tenderness, uterine contractions or hypertonicity, vaginal bleeding, preterm labour, or an atypical or abnormal EFM tracing. Specific sonographic findings are uncommon; retroplacental hematoma is seen in 2% to 25% of abruptions. Treatment should never be delayed for ultrasound confirmation because ultrasonography is not reliable in diagnosing placental abruption. In a study of 149 women with vaginal bleeding, the sensitivity, specificity, and positive and negative predictive values of sonography in diagnosing placental abruption were 24%, 96%, 88%, and 53%, respectively.[96] Some have suggested that traumatic abruption tends to be occult without uterine tenderness or vaginal bleeding but with a higher incidence of coagulopathy.[97] Abruption, occult or concealed, may lead to major maternal bleeding and consumption coagulopathy with thrombocytopenia, prolonged coagulation tests and hypofibrinogenemia.[57]

Although severe placental abruption can be lethal to the fetus, a timely and prompt Caesarean section may result in considerable survival rates of up to 75%.[34,98] Delay in recognition of non-reassuring fetal status, in such cases, was accountable for 60% of potentially preventable perinatal deaths. In cases of a non-viable fetus, vaginal birth is preferable. Although placental abruption, particularly with greater than 50% placental separation, increases the risk of fetal death, it more often results in preterm labour. Placental abruption is often associated with a rapid cervical dilation and delivery, induction or augmentation of labour with a trial of vaginal birth may be reasonable in a hemodynamically stable mother at or near term with a normal fetal heart rate pattern. However, in the presence of fetal or maternal compromise, prompt delivery by Caesarean is often indicated. Maternal bleeding and coagulation abnormalities should be aggressively treated to optimize maternal and fetal outcome. Abruption remote from term is challenging to manage. Deterioration in fetal condition or maternal hemodynamic instability is indications for immediate delivery, even at the expense of prematurity.[95]

Uterine Rupture

Post-trauma uterine rupture is rare (0.6% of all maternal injuries), but seen more frequently with a scarred uterus or with direct abdominal impact during the latter half of pregnancy.[74] Most (75%) uterine ruptures involve the fundal area. The degree of rupture may vary from complete avulsion of the uterus to serosal hemorrhage and abrasions. Symptoms and signs suggestive of uterine rupture include: maternal shock, abdominal distension, irregular uterine contour, palpable fetal parts, sudden abnormal fetal heart rate pattern, ascent of fetal presenting part and peritoneal irritation (abdominal rigidity, guarding and tenderness). Maternal mortality has been described with traumatic uterine rupture and fetal mortality is almost universal. It is the cause of MVC-related perinatal death in 17.5% of the cases.[8] Suspected uterine rupture with maternal and/or fetal comprise should prompt urgent laparotomy to control bleeding and facilitate resuscitation.

Preterm Labour

Traumatic injury during pregnancy can result in preterm labour through several mechanisms. Placental abruption may culminate in preterm labour in 20% of cases.[99] The extravasation of blood at the placental margin may lead to decidual necrosis, which, in turn, could initiate the production of prostaglandin, thereby leading to preterm labour.[99] Traumatic injury to the uterus may also result in destabilization of lysosomal enzymes which can initiate prostaglandin production.[68] Preterm premature rupture of membranes is also associated with preterm labour. Regardless of the mechanism, trauma (even with minor injuries) is associated with a 2-fold higher risk of preterm delivery.[100] The risk is higher with increasing injury severity and among those injured early in gestation.[100] Signs of

preterm labour should be sought in every patient with a viable fetus. EFM should be used to assess regularity and frequency of contractions. When regular contractions are noted, the fetal fibronectin test or cervical length assessment to determine the risk for preterm labour should be considered. Rupture of the membranes, when suspected, should be ruled out by a speculum examination including assessment with nitrazine paper and the ferning test. If risk of preterm delivery is high because of preterm labour or preterm premature rupture of membranes, steroids (and any other indicated medications such as antibiotics and magnesium sulfate), transfer to a tertiary care centre, and neonatology consultation should be considered based on gestational age and current location of the patient. In many cases, iatrogenic preterm delivery may be indicated to improve fetal or maternal outcome.

Direct Fetal Injury

Direct fetal injury is seen in less than 1% of blunt maternal trauma.[101] Maternal soft tissues, uterus, and amniotic fluid serve to diminish the force delivered to the fetus. Direct fetal injury from blunt abdominal trauma often involves the fetal skull and brain. One possible mechanism involves fracture of the maternal pelvis in late gestation with an engaged fetal head resulting in fetal skull fracture.[102] A deceleration injury of an unengaged head can also occur.[103] Fetal injuries in other modes of maternal trauma are considered in the section below.

Recommendation

27. Management of suspected placental abruption should not be delayed pending confirmation by ultrasonography; ultrasound is not a sensitive tool for its diagnosis. (II-3B)

ADDITIONAL CONSIDERATIONS REGARDING SPECIFIC TRAUMATIC INJURIES

Penetrating Trauma

Penetrating trauma during pregnancy is becoming more common. Penetrating abdominal injuries are caused primarily by gunshot or stab wounds. As in non-pregnant individuals, stab wounds tend to have a better prognosis than gunshot wounds. The maternal bowel is less likely to be involved with penetrating injuries after the second trimester due to the protection provided by the large uterus. The incidence of maternal visceral injury with penetrating abdominal trauma is only 15% to 40% compared with 80% to 90% in non-pregnant women.[35] Although the visceral organs are displaced upwards and are less likely to be injured, upper abdominal stab wounds can result in more complex bowel injury. Thoraco-abdominal penetrating injuries, below the fourth intercostal space anteriorly, or the tip of the scapula posteriorly, may cause visceral injuries that are easily missed. At the same time that the gravid, abdominal uterus provides protection to the abdominal viscera, it is susceptible, along with the fetus, to direct injury. According to Buchsbaum, the uterine musculature absorbs a great amount of the projectile's velocity and diminishes its ability to damage the viscera.[29] Therefore, depending on the gestational age and the size of the uterus, the fetus is much more likely than the mother to sustain significant injury (and to die) after a penetrating abdominal trauma. In general, the fetus sustains injury in 60% to 70% of cases, while visceral maternal injuries are seen only in 20% of penetrating abdominal trauma.

Gunshot wounds produce transient shock waves and cavitations in displacement of kinetic energy to body tissue, causing more damage and thus higher mortality for both mother and fetus than low-velocity injuries: 70% of abdominal gunshot wounds result in fetal injury, and 40% to 65% of these fetuses die.[104] Fetal mortality generally results from premature delivery, maternal shock, uteroplacental injury, or direct fetal injury.[105] A study of 321 pregnant trauma patients showed that 9% had penetrating trauma, of which 73% were gunshot wounds.[4] The risk of maternal death was not significantly higher with penetrating trauma than with blunt trauma (7% vs. 2%); however, fetal mortality was significantly higher (75% vs. 10%) with penetrating trauma.

Penetrating injuries in pregnant trauma patients are managed in essentially the same way as in non-pregnant patients. The standard of care is to prioritize the emergent treatment of the gravid patient above that of her fetus. The hemodynamically stable patient should be assessed by non-invasive diagnostic methods such as ultrasound and triple contrast CT scan. The same indications for surgical exploration apply as in the non-pregnant patient (positive findings on lavage, free air under the diaphragm before lavage, progressive abdominal distention with a declining hematocrit, or abdominal wall disruption or perforation). In cases of exploration, the decision to proceed with Caesarean section should be weighed against the likelihood for fetal survival and long-term complications of prematurity and should be made in consultation with the trauma surgeon, neonatologist, and pediatric surgeon. Factors that can influence the decision to proceed with Caesarean section are gestational age, extent and severity of fetal injury, degree of uteroplacental compromise, parameters of fetal well-being, and the need for hysterectomy with extensive uterine injury. A dead or injured fetus is not considered an indication for exploration, as the fetus will usually spontaneously

abort or can be delivered vaginally. Tetanus vaccination is safe in pregnancy and should be given, when indicated, according to the usual protocol.[106,107]

Domestic or Intimate Partner Violence

The incidence of domestic or intimate partner violence increases during pregnancy and is clustered in the third trimester.[6,108] Domestic violence was reported by 6.6% of pregnant women in Ontario.[108] The most commonly struck body area was the abdomen (64%), a risk factor for both maternal and fetal adverse outcome. Other studies have reported an even higher incidence of abuse during pregnancy (10–30%), with 5% resulting in fetal death.[109,110] Every woman who sustains trauma, particularly penetrating abdominal trauma, should be questioned specifically about domestic violence. Careful, detailed, and contemporaneous documentation is essential. Such inquiry should occur in the absence of the partner.

Motor Vehicle Collision

In the pregnant population, MVC is the leading cause of maternal death, and after placental abruption, maternal death is the leading cause of fetal death.[111,112] Of 351 maternal deaths from non-obstetric causes in a trauma centre registry, 72% resulted from MVC.[113] Documentation of the nature of the injury and of maternal and fetal status is important for reasons that include evaluating whether any subsequent adverse outcome should be attributed to the MVC.

The outcome of MVC can range from no trauma at all to severe multi-organ damage and death. The outcome is related to various factors including the mechanism of the collision itself, the acceleration-deceleration velocities of the vehicles involved, and the use of protective mechanisms, such as seat belts, air bags, and other safety features. Wearing a seat belt in a motor vehicle during pregnancy is useful and effective in reducing the risk of adverse pregnancy outcomes including maternal death.[113,114] Crosby and Costiloe reported a reduction in the maternal death rate from 33% to 5% with the use of a two-point seatbelt, and that finding was reproduced by a more recent study.[112,115] During prenatal visits, the caregiver should emphasize the importance of wearing a properly adjusted and positioned seatbelt at all times and refute any misconception about the use of seatbelts during pregnancy.[116] Ejection from the vehicle increases the risk to both the woman and the fetus. The lap belt should be positioned below the abdomen and not over the uterus. The shoulder belt should be placed between the breasts. The belt should be comfortable, but not tight. Air bags are a relatively newer modality in preventing and reducing injuries in MVC. In a simulated study, a combination of seatbelts and air bag was the most beneficial, and could be lifesaving in severe MVC.[117] Deployment of airbags has been associated with adverse events such as uterine rupture, placental abruption, and fetal death that were attributed to the air bags.[113,118,119] However, this is more likely a reflection of the severity of traumatic force rather than a causal association. At this point there are not enough data to make a recommendation about disabling air bags during pregnancy. Furthermore, when the risk of fetal death or injury is balanced against risks to the mother, the latter should take precedence, recognizing the fact that fetal well-being is dependent on maternal well-being.

Although organ damage, fractures, and hemorrhage can occur in MVC, the most common mechanism of injury is blunt trauma, which can cause both maternal and fetal morbidity and mortality. The mechanism of trauma often involves the uterus. A force applied to the uterus can deform the shape of the uterus due to its elasticity, but can have a smaller deforming effect on the less elastic placenta. This can result in a shearing force that may separate the attached placenta from the uterus. Abrupt changes in amniotic fluid pressure may further contribute to placental separation. The end result of this kind of mechanism is placental abruption. One report suggested that up to 37% of life-threatening maternal injuries after MVC are complicated by abruption, whereas in non–life-threatening injuries, the incidence of abruption was only 1.6%.[120] Uterine contractions may also result from blunt trauma and lead to preterm labour. Relatively minor injuries may be associated with a grave pregnancy outcome.[121] Maternal–fetal hemorrhage may be a serious complication of blunt trauma. Exsanguination into maternal circulation can occasionally culminate in fetal demise. Direct fetal intracranial injury is another, albeit uncommon, mechanism of fetal injury.[122] This type of injury may be attributed to a direct trauma to the fetal head but may also result from a massive maternal–fetal hemorrhage and significant fetal hypotension with subsequent hypoxic-ischemic intracranial injury.

Falls

Falls are the cause in 3% to 31% of cases of maternal trauma.[69,123] Less than 10% of falls are associated with significant maternal or fetal complications.[124] They are more common in the latter half of pregnancy, particularly after 32 weeks.[69,74] The increase in lumbar lordosis that is seen in pregnancy moves the centre of gravity forward and contributes to an increased incidence of falls.[123] Therefore, aggressive high-impact activity should be avoided in advanced pregnancy. Complications associated

with falls include preterm labour, placental abruption, uterine rupture, fetal growth restriction, and fetal death.[123]

Electrical Trauma

Electrical shock is the fifth leading cause of fatal occupational injuries in the United States and most commonly result from failure to ground appliances properly or from using electrical devices while wet.[125] The literature on maternal electrical trauma is scarce and possibly misleading due to publication bias stemming from the tendency to report adverse outcomes rather than uneventful insults. Nevertheless, several case series have emphasized poor fetal outcome of electrical trauma. Fatovich reviewed the literature and found 15 cases of maternal electric shock with a fetal mortality rate of 73% and only 1 normal pregnancy outcome.[126] The Motherisk Program published a prospective cohort study of 31 pregnant women with electric shock who sought experts' advice via telephone[127]; 28 of those women delivered healthy newborns. One spontaneous abortion was temporally related to the insult, another was probably unrelated to the injury, and a third baby was born with a ventricular septal defect. Mean birth weight, gestational age at delivery, rates of Caesarean section, and incidence of neonatal distress were similar between electric shock and control groups.[127] Several risk factors for adverse perinatal outcome were identified. The magnitude of the current obviously has an impact on outcome. The pathway of the current in the body, from entrance to exit points, is of utmost importance. A current that travels from the hand to the foot will probably go through the uterus, stimulating myometrial contractions, which may culminate in preterm labour.[127] Electrical current that traverses the amniotic fluid (an excellent conductor) may lead to spontaneous abortion, fetal demise, or fetal burns.[128] Other risk factors include maternal body weight, blunt trauma following the electrical insult, and being wet.

Maternal and fetal assessment is warranted in cases of electrical injury during pregnancy.[129] Electrocardiography, urine tests for major muscle injury, X-ray imaging, and sometimes CT are all part of the initial evaluation of the mother. With a viable fetus, EFM is recommended for 24 hours if the injury involved loss of consciousness, abnormal maternal ECG, or known maternal cardiovascular illness. In most other cases, and especially if the insult involved low voltage, immediate fetal effects are unlikely.

Summary Statement

At this time, there is insufficient evidence to support the practice of disabling air bags for pregnant women. (III)

Recommendations

28. Tetanus vaccination is safe in pregnancy and should be given when indicated. (II-3B)
29. Every woman who sustains trauma should be questioned specifically about domestic or intimate partner violence. (II-3B)
30. During prenatal visits, the caregiver should emphasize the importance of wearing seatbelts properly at all times. (II-2B)

PERIMORTEM CAESAREAN SECTION

The concept of performing Caesarean section concurrent with maternal resuscitation was introduced in 1986 when it was recommended that the procedure should be done no later than 4 minutes following maternal cardiac arrest.[130,131] The rationale for the recommendation was improved efficacy of maternal chest compression after delivery by alleviating the aortocaval compression exerted by the gravid uterus and allowing adequate venous return. Neurologic injury in the mother begins 6 minutes after cessation of cerebral blood flow; to obtain cardiac return by 5 minutes and avoid neurological damage the Caesarean section should be started 4 minutes after the maternal pulse ceases.[24,41,132] A perimortem Caesarean section is recommended for viable pregnancies (≥ 23 weeks, or fundal height 2 or more fingerbreadths above the umbilicus).[132] In these cases, not only is the uterus large enough to cause significant aortocaval compression (its emptying therefore allowing improved maternal cardiac output), the baby is also mature enough that it may survive the event even if the mother does not.[132] Prolonged resuscitation is not recommended if no pulse can be obtained, and the uterus should be emptied to increase the likelihood of successful maternal resuscitation and a healthy infant. In many trauma cases, resuscitation will be futile because of a fatal cause. In such cases, there is no reason to delay Caesarean section to save a viable fetus. It should be emphasized that many studies and case reports relate non-traumatic cardiac arrests in which the maternal resuscitation efforts were the major indication for delivery. Trauma patients with cardiac arrest are less likely to respond to resuscitation; in these cases, perimortem Caesarean is performed primarily for fetal salvage. Delivery of a viable neonate is less likely when no maternal vital signs have been recorded for 15 to 20 minutes.[131,132] A multi-institutional retrospective cohort study showed that of 33 fetuses delivered by emergency Caesarean section in the setting of maternal trauma, 13 had no fetal heart tones at the initiation of the Caesarean section and none survived. When no fetal

heart tones can be demonstrated at initial assessment of a pregnant trauma patient after 23 weeks' gestation, Caesarean section is likely to be futile in terms of fetal survival.[34]

Recommendation

31. A Caesarean section is recommended for viable pregnancies (≥ 23 weeks) no later than 4 minutes (when possible) following maternal cardiac arrest to aid with maternal resuscitation and fetal salvage. (III-B)

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