Orthopaedic Trauma in the Pregnant Patient

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Abstract

Trauma affects up to 8% of pregnancies and is the leading cause of death among pregnant women in the United States. A pregnancy test is mandated for all females of childbearing age who are involved in trauma. Orthopaedic trauma in the pregnant patient is managed similarly to that for all trauma patients. Initial resuscitation efforts should focus on the pregnant patient because stable patient vital signs provide the best chance for fetal survival. In the stable patient, fetal assessment and a pelvic examination are mandatory. Radiographs as well as abdominal ultrasound of the patient and fetal ultrasound are useful. No known biologic risks are associated with magnetic resonance imaging, and no specific fetal abnormalities have been linked with standard low-intensity magnetic resonance imaging. Emergency surgery can be safely performed in most pregnant patients. Avoiding patient hypotension and using left lateral decubitus positioning increase the likelihood of success for the patient and fetus. An experienced multidisciplinary team consisting of an obstetrician, perinatologist, orthopaedic surgeon, anesthesiologist, radiologist, and nursing staff will optimize the treatment of both the pregnant patient and her fetus.

Trauma affects as many as 8% of pregnancies and is the leading cause of maternal death in the United States.[1-4] Because the fetus is fully dependent on the physiology of the pregnant patient, proper patient resuscitation is the best fetal resuscitation.[3] Similarly, although both patient and fetal investigations are necessary, the initial management of any severe trauma should focus first on the pregnant patient. Most circumstances that may lead to maternal instability (eg, hypotension) also will be catastrophic for the fetus. Therefore, treatment algorithms and priorities according to the Advanced Trauma Life Support standards are similar for both the pregnant and the nonpregnant trauma patient.[5] Fetal evaluation should not interfere with assessment of potentially life-threatening injuries in the pregnant patient.

Epidemiology

Trauma is the primary cause of nonobstetric-related death during pregnancy; as such, it is of great concern to trauma surgeons and gynecologists.[6,7] Motor vehicle accidents account for a large portion of blunt trauma during pregnancy and are the leading cause of death in girls and women aged 8 through 28 years.[8] Domestic violence, another common cause of trauma during pregnancy, is involved in 10% of cases.[1,9] Approximately 0.3% to 0.4% of

Table 1

Important Physiologic Changes During Pregnancy

Parameter	Change	Implication
Maternal blood volume	Increased	Attenuated initial response to hemorrhage
Cardiac output	Increased	Increased metabolic demands
Uterine size	Enlarged	Potential for supine hypotension from aortocaval compression
Functional lung residual volume	Decreased	Hypoxemia from atelectasis
Gastrointestinal motility	Decreased	Greater risk for aspiration
Minute ventilation	Increased	Compensated respiratory alkalosis

Adapted with permission from Van Hook JW: Trauma in pregnancy. *Clin Obstet Gynecol* 2002;45:414-424.

Table 2

Physiologic Changes Affecting Diagnosis and Treatment of the Pregnant Patient With an Orthopaedic Injury

First Trimester
- Major organogenesis (radiosensitive)
- Central nervous system development (most sensitive period)
- Increased risk of teratogenesis
- Elevated white blood cell count may be normal
- Elevated erythrocyte sedimentation rate may be normal
- Hypercoagulable state
- Increased risk of spontaneous abortion related to general anesthesia

Second Trimester
- Fetal central nervous system relatively radioresistant
- Hypotension possible with supine positioning caused by aortocaval compression (as a result of increased uterus size)
- Elevated white blood cell count may be normal
- Elevated erythrocyte sedimentation rate may be physiologically normal
- Hypercoagulable state
- Increased risk of spontaneous abortion related to general anesthesia
- Increased risk of seat belt–related injury to the fetus

Third Trimester
- Maternal plasma expands by 40% to 50% (dilutional anemia)
- Pregnancy-related osteoporosis possible
- Increased risk of seat belt–related injury to the fetus
- Elevated white blood cell count may be physiologically normal
- Elevated erythrocyte sedimentation rate may be physiologically normal

traumatized pregnant patients require hospital admission; as many as 24% of these patients die as a result of their injuries.[10,11] Maternal trauma is also the leading nonobstetric cause of fetal death.[3] In addition to high-energy trauma and domestic violence, pregnancy-related osteoporosis may be present during the third trimester and may contribute to fractures in some women after relatively minor injuries.[12-17]

Proper evaluation of trauma in the pregnant patient requires a clear understanding of the severity of the injury and its relation to both the pregnant patient and the fetus. Inadequate management not only will have adverse consequences for the patient but also may be disastrous for the fetus.

Key Physiologic Changes During Pregnancy

Numerous changes in the pregnant female's anatomy and physiology must be considered during emergency orthopaedic care (Table 1). In the pregnant woman, plasma volume expands by 40% to 50% by the end of the first trimester (Table 2). Red blood cell mass also expands, but less so than plasma volume, resulting in a dilutional anemia and a corresponding small decrease in hematocrit level. This adaptive preparation for blood loss during childbirth provides greater tolerance to blood loss in a trauma situation. The physician caring for a pregnant patient with traumatic blood loss must avoid a false sense of assurance regarding the degree of hemorrhage or hemodynamic instability. Clinically, blood loss up to 2,000 mL (30%) may not be readily apparent in the pregnant patient because mean arterial pressure often remains stable. Although shock in the patient may be obscured by the altered physiology of pregnancy, a 30% loss in patient blood may decrease placental flow by 10% to 20%.[18] In addition, cardiac output increases during pregnancy, peaking 35% to 50% above baseline at 28 to 32 weeks' gestation.[8]

Another important hemodynamic consideration in the pregnant trauma patient is the potential hypotensive effect of supine positioning. This effect, which is caused by aortocaval compression by the enlarged uterus, may decrease cardiac output by 25%. Use of a right hip wedge, manual displacement of the

uterus, or lateral tilt positioning of the patient may help avoid this situation. White blood cell count may be normally elevated to 18,000/mm^3 during pregnancy. Leukocytosis and erythrocyte sedimentation rate are unreliable indicators of infection in the pregnant patient.

Finally, a hypercoagulable state exists because of an increase in clotting factors and fibrinogen levels. This is important to consider in the postoperative immobilization phases with regard to the crucial need for prophylaxis for deep vein thrombosis. Therapeutic doses of subcutaneous fractionated heparin with sequential compression boots should be routinely used whenever possible. Warfarin is contraindicated.

Initial Evaluation

Pregnancy alters neither the standard primary survey of the injured patient (airway evaluation, breathing, and circulation) nor the usual diagnostic pharmacologic or resuscitative procedures and interventions.[5] Placing the patient on a backboard with a 15° angle to the left is a pregnancy-specific intervention that should be used in all patients beyond the 20-week gestation period. This precaution partially relieves the compressive effect of the uterus on the vena cava, which can reduce maternal cardiac output up to 30%.[19]

A diagnosis of pregnancy should be made early during patient evaluation. A urine pregnancy test initially and/or a serum β-hCG (human chorionic gonadotropin) hormone test is mandatory in all women of childbearing age who are involved in trauma.[20] With the pregnant patient, gestational age is important for decisions related to further fetal surveillance and patient care. Beyond gestational week 20, simultaneous monitoring of fetal heart rate and uterine activity (cardiotocography) should begin in the emergency department, even in the patient with minor trauma. Hypovolemic shock may occur with minimal changes in pulse or blood pressure, and fetal distress may be the first sign of patient hemodynamic compromise.[18,21]

Patient medical, surgical, and pregnancy history is important because of the possibility of preexisting hypertension, eclampsia, and diabetes. As in all motor vehicle accidents, patient seat belt usage is important. Restraint during pregnancy has been shown to contribute to increased survival rates for both patient and fetus following motor vehicle accidents.[22] Research also suggests that many pregnant women (25% to 50%) do not follow established guidelines for seat belt use during pregnancy, indicating a need for increased educational outreach.[22]

The primary goal in managing the pregnant trauma patient should be evaluating and stabilizing her vital signs. Adequate oxygenation and pulse oximeter monitoring are important because hypoxia is a significant factor in fetal distress. The pregnant patient who appears to be hemodynamically stable may be silently compensating at the expense of the fetus. Therefore, an aggressive approach to resuscitation, diagnosis, and treatment is essential for these patients.[2] In general, the condition of the pregnant patient directly influences the fate of the fetus.[6,23-25] In the pregnant patient, a high Injury Severity Score and a low Glasgow Coma Scale score on admission are associated with adverse outcomes for the fetus.[6,26] Other important initial predictors of fetal mortality include low hemoglobin level on admission, longer hospitalizations, and the development of disseminated intravascular coagulation.[6]

After ensuring patient stability, fetal ultrasound provides useful information regarding fetal well-being. Fetal motion, bradycardia, tachycardia, and placental integrity may be rapidly evaluated with ultrasound.[21]

Radiographic Evaluation

The estimation by the general public of the dangers of diagnostic radiographs during pregnancy is exaggerated. The maximum recommended dose by the National Council on Radiation Protection During Pregnancy is 50 mGy (5 rad).[27] Potential effects of radiation to the fetus may be grouped into three categories: teratogenesis (fetal malformation), carcinogenesis (induced malignancy), and mutagenesis (alteration of germ-line genes). Teratogenesis relates largely to central nervous system (CNS) changes, such as microcephaly and mental retardation. A linear dose-related association between mental retardation and radiation exists, but this association is not statistically significant at doses generated by diagnostic radiography.[27] The dosage required to double the baseline mutation rate is between 50 and 100 rad, far in excess of the doses received during most diagnostic studies.[27]

During pregnancy, the radiation-absorbed dose to the fetus is of greater concern than the maternal dose because the fetus' cells are rapidly dividing and thus are more radiosensitive. Major organogenesis occurs during weeks 3 through 8; substantial radiation to the fetus during this time may cause malformation. Primarily up to week 15, the CNS is the most sensitive organ system. After week 25, the fetal CNS is relatively radioresistant.[28] According to Timins,[28] absorption by the fetus of <100 mGy (10 rad) does not increase the risk of fetal death, malformation, or impaired mental development. Between weeks 8 and 15, doses of 200 to 500 mGy (20 to 50 rad) may result in a measurable reduction in IQ. Doses >500 mGy (50 rad) are associated with a higher incidence of growth retardation and CNS damage.[27,28]

Most diagnostic radiographs and nuclear medicine studies result in fetal radiation doses that are well be-

Table 3

Fetal Radiation Exposure (Approximate) During Common Radiographic Studies

Radiographic Study	Rad	No. of Studies to Reach Cumulative 5 rad
Cervical spine	0.002	2,500
Chest (two views)	0.00007	71,429
Pelvis	0.040	125
Hip (single view)	0.213	23
CT head (10 slices)	<0.050	>100
CT chest (10 slices)	<0.100	>50
CT abdomen (10 slices)	2.600	1
CT lumbar spine (5 slices)	3.500	1
Ventilation-perfusion scan	0.215	23

CT = computed tomography

Adapted with permission from Toppenberg KS, Hill DA, Miller DP: Safety of radiographic imaging during pregnancy. *Am Fam Physician* 1999;59:1813-1820.

low the threshold of risk (Table 3). For example, a single radiograph of the pelvis yields only 0.040 rad. Nonetheless, all radiographs should be performed so as to minimize the amount of exposure to the fetus. Collimation of the x-ray beam and shielding the fetus with a lead apron may help accomplish this goal. A clear perception of the actual risks and benefits of radiographic studies during pregnancy is required to ensure proper patient care and counsel.

There are no known biologic risks associated with magnetic resonance imaging (MRI), and no specific fetal abnormalities have been linked with standard low-intensity MRI scanning. In their study of children aged 9 months who had had an MRI performed in utero, Clements et al[29] reported no abnormalities related to that MRI.

The primary x-ray survey of any trauma patient should include a lateral cervical spine, an anteroposterior chest, and an anteroposterior pelvic radiograph. Placing a lead shield over the abdomen whenever possible provides additional protection for the fetus. Abdominal ultrasound has similar efficacy for evaluating abdominal trauma in pregnant and nonpregnant patients; it should be used as required by the trauma team.[30]

In general, computed tomography (CT) is an excellent rapid screening modality, although radiation doses are significantly higher than those from plain radiographs. Spiral CT is advantageous because it can scan a large volume in a short time. A CT scan may show uterine rupture or placental separation. When a CT scan is required for further evaluation of a pelvic ring injury or for surgical planning, patients should be made aware of the slight possibility of induced carcinogenesis in all stages of pregnancy (0.2% to 0.8% for pelvic CT delivering a 5-rad dose).[31]

The cervical spine and the thorax may be evaluated with proper (lead) apron protection, in accordance with the Advanced Trauma Life Support protocol. When further evaluation of the spine is needed, the use of MRI is warranted and safe. When MRI is unavailable, selective use of CT scanning should be used based on evaluation of the risks of radiation exposure versus the possible benefit of the CT scan.[31]

Anesthetic and Perioperative Medication

Several concerns regarding anesthesia are associated with the pregnant patient. Brodsky et al[32] and Steinberg and Santos[33] studied surgical anesthesia during pregnancy and fetal outcome; they advocate postponing purely elective surgery until the postpartum period. If possible, they recommend deferring necessary surgery until after the first trimester. However, postponing surgery is not always feasible in the orthopaedic trauma patient.

The most critical time for chemical exposure in humans is thought to be during major organogenesis, generally between gestation day 15 and day 65.[34] Mazze and Kallen[35] carefully reviewed 5,405 women who received anesthesia during pregnancy and found no increase in congenital abnormalities or stillbirths. They did find an increased incidence of low-birth-weight infants, however, because of prematurity and intrauterine growth retardation. This study is corroborated by Duncan et al,[34] who found no increase in congenital anomalies between a group of 2,565 pregnant women who were operated on and a matched group of women who were not operated on. They did, however, find an increased risk of spontaneous abortion in the group that had undergone surgery with general anesthesia in the first or second trimester. In a smaller study, Brodsky et al[32] reported no increase in congenital anomalies in the infants born to 287 women who underwent surgery during pregnancy. They did report a slightly higher rate of spontaneous abortion, however.

The Collaborative Perinatal Project showed that the administration of local anesthetics such as benzocaine, procaine, tetracaine, and lidocaine during pregnancy did not result in an increased rate of fetal malformation.[33] Thus, with the ex-

ception of cocaine, local anesthetics administered for clinical use do not seem to be teratogenic.

Although spinal or epidural anesthesia is safe, there is a decreasing drug requirement for spinal or epidural anesthesia with advancing gestation because epidural venous engorgement reduces the volume of cerebrospinal fluid and the epidural space.[33] Supplemental sedation, often required as an adjunct to local blocks, may be minimized or avoided with the use of a spinal anesthetic.

Maternal hypotension associated with sympathetic blockade from spinal or epidural anesthesia is a primary concern because it may cause decreased uterine blood flow. As such, frequent blood pressure measurements should be obtained during the surgical procedure. At all times, hypotension and hypoxia in the pregnant patient must be avoided in order to reduce the likelihood of fetal distress.

When possible, inotropes or pressors should be avoided during the resuscitative phase because they cause a reduction in uteroplacental blood flow. Volume replacement should be maximized before their use. Regional anesthesia reduces the risk of aspiration, which is already higher than in nonpregnant patients because of decreased gastric motility during pregnancy. Regional anesthesia carries an increased risk of hypotension, more often with spinal than with epidural regional anesthesia.[33]

Antibiotics should be given at the same dosing schedule and for the same indication as for the nonpregnant patient. The safest antibiotics during pregnancy include the cephalosporins and penicillins, or an erythromycin. The administration of prophylactic cefazolin preoperatively and for 24 hours postoperatively is a safe procedure in the nonallergic patient. Antibiotic treatment of open fracture should follow the guidelines described by Gustilo and Anderson.[36] Tetanus prophylaxis should be administered according to the standard protocol: 0.5 mL intramuscular tetanus toxoid in the fully immunized patient who has not had a booster within 5 years; tetanus toxoid plus passive immunization in the patient who has not received a full course of immunization in the past. There is no known risk for either the pregnant patient or the fetus.

Pregnancy is considered a hypercoagulable state, which, coupled with prolonged immobilization because of trauma, places a woman at increased risk of thrombosis. A prophylactic dose of any of the readily available commercial fractionated heparins thus should be administered. Warfarin, as well as its chemical subcomponents, crosses the placenta, has teratogenic potential, and may cause fetal bleeding. Therefore, its use is not recommended.[37] Unfractionated heparin and low-molecular-weight heparin do not cross the placenta and are safe for the fetus. Long-term treatment with unfractionated heparin is problematic because of its inconvenient administration, the need to monitor anticoagulant activity, and its potential side effects to the patient, such as heparin-induced thrombocytopenia and osteoporosis.[37] Low-molecular-weight heparin is safe in the prevention and treatment of venous thromboembolism during pregnancy because of its ease of administration and its lower risk of side effects.[37]

Because of increased metabolic and caloric requirements during pregnancy, early initiation of total enteral nutrition should be considered in the patient who is unable to eat.

Surgical Indications

For the orthopaedic surgeon, safe, expedient, and appropriate treatment of the patient's injury is of paramount importance. In most instances, emergency surgery may be safely performed in a pregnant patient. There are several steps that the surgeon should take to optimize the outcome for both patient and fetus.

All orthopaedic emergencies should be treated as such, regardless of pregnancy status. Most extremity fractures are managed in the same manner that they would be in a nonpregnant patient. The radiation exposure to a fetus from extremity radiographs is minimal. An obvious exception is a radiograph of the proximal femur or pelvis, which exposes the fetus to more radiation than does an extremity radiograph. Therefore, it is reasonable, for example, to choose a surgical technique for femoral fractures that would limit the amount of radiation needed to satisfactorily accomplish the goal of fixation (ie, open plating versus intramedullary nailing). Whenever possible, an injury that would otherwise lead to a prolonged period of bed rest should be surgically addressed to enable early mobilization. The potential comorbidities associated with inactivity and bed rest likely outweigh the risks of surgery. As mentioned, elective orthopaedic procedures should be delayed until the postpartum period.

Pelvic fractures are of special interest in the pregnant patient because of the proximity of the uterus and the potential for severe blood loss. In the later stages of pregnancy, there is a possibility of high intra-abdominal pressure, which increases the risk of injuries to large vessels, such as the vena cava and, in particular, the pelvic veins. Also, as a result of the increased perfusion to the uterus and placenta associated with pregnancy, injury to this area is most often associated with severe hemorrhage. Severe bleeding from abruptio placentae may occur, which may necessitate an emergency hysterectomy.[24,25,38]

Pape et al[39] reported the results of seven pregnant patients with pelvic and/or acetabular fractures. The mean Injury Severity Score was 29.9

points. Two pregnant patients and four fetuses died as a result of these injuries. For two of three patients with live fetuses, treatment of the pelvic fracture was modified because of the pregnancy.

In the stable pregnant patient requiring surgery, modern ultrasound techniques may be used to easily monitor fetal heart rate during the operation. When the patient is under general anesthesia, the fetus also will be anesthetized, resulting in a heart rate pattern without any variability.[40] However, when decreased blood flow to the uterus leads to fetal hypoxia, the fetal heart rate will exhibit decelerations. Heart rate deceleration should alert the anesthesiologist that blood pressure may be changing or that the patient should be repositioned.

Patient Positioning

Patient positioning must be determined with a focus on the well-being of the fetus. To avoid compression of the inferior vena cava in the patient who is in her second or third trimester, the left lateral decubitus position (left side down) should be used during anesthesia. This precaution partially relieves the compressive effect of the gravid uterus on the vena cava, which can reduce patient cardiac output up to 30%.[19]

Alterations in uteroplacental blood flow also may be avoided by maintaining adequate mean arterial pressure in the patient. Unfortunately, some fractures (eg, a left calcaneus fracture needing a lateral approach) cannot be surgically treated with the patient in the formal lateral decubitus position. In these patients, nonsurgical management may be the best option. Flexibility is required in patient positioning because some degree of lateral decubitus positioning is required in patients in the late second or third trimester of pregnancy.

Fracture Fixation Techniques

The ongoing evolution of surgical fracture care has resulted in a large armamentarium of fixation tools and techniques. Given the risks associated with radiation exposure, the orthopaedic surgeon should choose the fixation technique that requires the minimum amount of radiation without compromising fracture care.

Especially early in the pregnancy, when fetal development is most fragile, judicial and minimal use of radiography should be employed. The benefits and risks of each surgical technique and the experience of the surgeon should be carefully weighed. For instance, whereas the so-called minimally invasive (percutaneous) plating techniques are popular, they are associated with a steep learning curve, which often results in a high cumulative radiation exposure time. This is also true for intramedullary nailing of a comminuted long bone fracture that might be difficult to reduce before nail insertion. The comminution makes obtaining proper alignment for passage of a guidewire more difficult, potentially leading to additional radiation exposure. In these cases, the surgeon should consider open plating techniques that do not rely so heavily on radiographic control. A carefully developed surgical plan will help decrease surgical time while also preparing for potential intraoperative problems.

Both acetabular and pelvic fracture fixation warrant referral to a specialist. The pelvic or acetabular fracture requiring surgical reduction and fixation in the pregnant patient provides a formidable challenge for the treating surgeon. Only a few cases of surgical treatment of pelvic or acetabular fractures in association with pregnancy have been reported.[39,41-45] In a recent literature review covering the years 1932 through 2000, Leggon et al[4] identified a total of 101 reported cases of pelvic or acetabular fractures in pregnant patients. Three mechanisms of injury were identified: motor vehicle collision (73%), falls (14%), and pedestrian struck by a car (13%). Most patients (57%) were in their third trimester. Both mechanism of injury and injury severity were related to mortality rates. However, fracture designation (simple versus complex), fracture type (acetabular versus pelvic), the trimester of pregnancy, and the era in which the patient received treatment had no influence on mortality rates. Hemorrhage in the pregnant patient had a greater association with fetal demise than did direct trauma to the uterus, placenta, or fetus. The overall fetal mortality rate in pelvic and acetabular fractures was 35% versus a 9% patient mortality rate.[4]

A healed pelvic or acetabular fracture sustained during or before pregnancy (whether treated surgically or nonsurgically) does not represent an absolute contraindication to vaginal delivery, provided the pelvic architecture is not disrupted. With the pregnant patient, clinical and surgical decisions must be based on the nature of the injury, careful assessment of the clinical status of the patient and fetus, and evaluation of the risk-benefit ratio of the surgical procedure and its clinical consequences for both the patient and the fetus.

Summary

Evaluation and treatment of the pregnant patient with an orthopaedic injury present unique challenges to the orthopaedic surgeon. This scenario is often unfamiliar. Diagnostic evaluation and clinical decision making must be carefully considered and executed in a short period. Decisions must be made regarding the use and safety of radiographic studies, fetal monitoring, the timing and indications for surgical intervention, and the appropriate use of medications and anesthesia during and after surgery. An experienced multidisciplinary team comprising an obstetri-

cian, perinatologist, orthopaedic surgeon, anesthesiologist, radiologist, and nursing staff should be involved in caring for the pregnant trauma patient with musculoskeletal injuries. Thorough knowledge of the specific patient care issues related to the pregnant patient with an orthopaedic injury maximizes the chances for optimal outcomes for both the patient and the fetus.

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Evidence-based Medicine: The authors note that there are no level I or level II evidence-based studies.

Citation numbers printed in **bold type** indicate references published within the past 5 years.

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