A Review Paper

Orthopedic Trauma in Pregnancy

Pratik Desai, MD, and Michael Suk, MD, JD, MPH

Abstract

Trauma sustained during pregnancy can trigger uncertainty and anxiety for patient and orthopedic surgeon alike. In particular, orthopedic-related injuries raise concerns about preoperative, intraoperative, and postoperative care. In this article, we review common concerns about radiation exposure, leukemia, pain management, anticoagulation, and anesthesia. One finding is that radiation risk is minimal when obtaining x-rays for operative planning, provided that the cumulative dose is within 5 rad. We also address safety concerns about patient positioning and staff radiation exposure. In addition, we found that most anesthetics used in pregnancy are category C (ie, safe). Perioperative opioid use for pain management is recommended with little risk. Regarding anticoagulation, low-molecular-weight heparin and fondaparinux are the safest choices. Last, pregnancy is not a contraindication to operative management of pelvic and acetabular fractures.

Pregnancy elicits a component of musculoskeletal pain or discomfort for most women that has been well chronicled. In 1994, Heckman and Sassard[1] concisely reviewed musculoskeletal conditions encountered during pregnancy, such as low back pain, carpal tunnel syndrome, de Quervain tenosynovitis, leg cramps, and hip pain. They also commented on changes occurring during pregnancy of preexisting musculoskeletal conditions, such as rheumatoid arthritis and ankylosing spondylitis. Since their review appeared, other authors in the nonorthopedic literature have commented on similar conditions and physical examination maneuvers to elicit them.[2]

The case that we describe here led us to search the literature for answers to practical concerns in global fracture management during pregnancy. It quickly became clear that this search would be labor-intensive and would yield many sources but few from the orthopedic literature. We include our findings in this article, which can be considered a useful resource for orthopedic surgeons.

Dr. Desai is a Resident, Department of Orthopaedics and Rehabilitation, and Dr. Suk is Assistant Professor and Director, Orthopaedic Trauma Service, Department of Orthopaedics and Rehabilitation, University of Florida Health Science Center, Jacksonville, Florida.

Requests for reprints: Pratik Desai, MD, Department of Orthopaedics and Rehabilitation, 655 W 8th St, ACC Building, 2nd Floor, University of Florida Health Science Center, Jacksonville, FL 32209 (tel, 904-244-7757; fax, 904-244-3457; e-mail, pratik.desai@jax.ufl.edu).

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We include practical considerations pertaining to preoperative, operative, and postoperative management of orthopedic injury during pregnancy. Through a review of the literature of the past 25 years, we provide the orthopedic community with current information from multidisciplinary sources to assist in global fracture management. We focus on concerns involving radiation exposure, anesthesia, pain control, anticoagulation, and treatment of pelvic/acetabular fractures.

"[This paper provides] a review of the literature of the past 25 years."

Case Example

A woman in her early 20s with a 24-week intrauterine pregnancy (IUP) sustained an isolated closed femur fracture as an unrestrained driver in a motor vehicle collision and presented to the trauma center at our institution. She had no prior medical or surgical history. On physical examination, she had a visible deformity about her right thigh without any open wounds. She was neurovascularly intact. X-rays showed a midshaft femur fracture with moderate displacement. Focused assessment with sonography for trauma (FAST study) revealed good fetal motion and fetal indices (Figures 1, 2). A consultation with obstetricians was obtained because of questions about fetal monitoring and risks associated with intramedullary nailing, anesthesia, pain medication, and anticoagulation. In their judgment, fetal monitoring was unnecessary, as the fetus was still nonviable (≤24 weeks IUP). No anticoagulation was necessary, as the patient was ambulatory immediately after surgery. The patient had no other associated injuries, and a multidisciplinary decision was made to take the patient emergently to the operating room.

A retrograde intramedullary nail was placed without complications under fluoroscopic guidance (Figure 3). The patient was discharged on postoperative day 3. At 34 weeks gestation, she began weight-bearing as tolerated and had minor knee pain.

Radiation Exposure

One of the most anxiety-provoking aspects of fracture care for patient and physician is radiation exposure to the mother and fetus and possible teratogenesis.

Risk Perception

Results from numerous studies of nuclear bomb survivors have shown that the teratogenicity of radiation is dose-

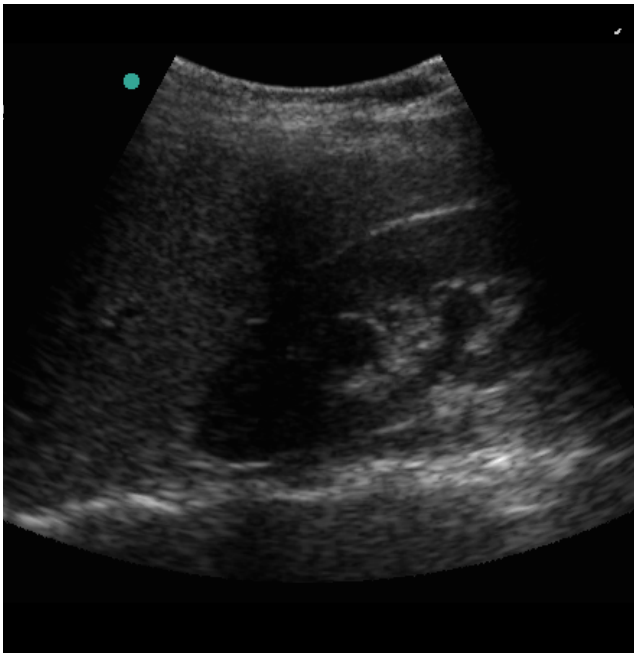

Figure 1. Ultrasound at 24-week intrauterine pregnancy.

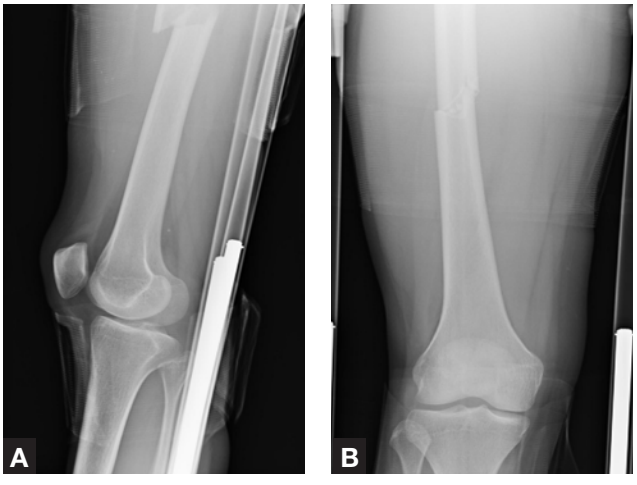

Figure 2. Lateral (A) and anteroposterior (B) x-rays of injury.

dependent. In addition, the most critical and vulnerable period in utero for central nervous system damage is 8 to 15 weeks of gestation. However, in a recent review of the literature, De Santis and colleagues[3] found that, though ionizing radiation represents a possible teratogen to the fetus, "inadvertent exposure[s] from diagnostic procedures in pregnancy … do not in most cases increase the natural risk of congenital anomalies." Furthermore, they recommended that, if a maternal indication for radiologic imaging exists, and the information cannot be obtained by other methods, the physician should not hesitate to order such studies. The only caveat they offered was that maternal thyroid gland exposure to diagnostic radiation was associated with slight decreases in birth weight.

Physicians' perceptions of teratogenic risk associated with radiation exposure in early pregnancy were recently studied.[4] Four hundred family physicians and 100 obstetricians were asked about their perceptions of risk to offspring associated with any abdominal plain x-ray or computed tomography (CT) scan. Although subjects were informed of the baseline of 1% to 3% risk of major malformations in any pregnancy, results proved that the perceived risks were unrealistically high and warranted education of the medical community. Forty-four percent of family physicians and 11% of obstetricians estimated the risk to be higher than 5% with abdominal x-ray, and 61% of family physicians and 34% of obstetricians estimated the risk to be higher than 5% with abdominal CT. Undoubtedly, such misperceptions can lead to increased maternal anxiety and incorrect recommendations to terminate pregnancy. The American College of Obstetricians and Gynecologists[5] provided guidelines for x-ray examinations or exposure during pregnancy (Table I).

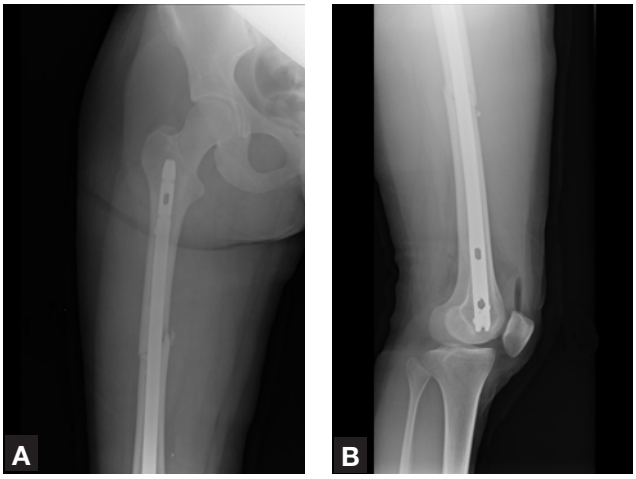

Figure 3. Anteroposterior (A) and lateral (B) postoperative x-rays.

Imaging Guidelines

Units generally used to measure the effects of x-ray include rad, roentgen equivalents man (rem), gray (Gy), and sievert (Sv). In the literature, any of these units may be used, and it is therefore important to understand their conversions. For the purpose of diagnostic x-rays, 1 Gy = 1 Sv = 100 rad = 100 rem. Fetal risks of growth restriction, anomalies, and abortions are not increased with ionizing radiation exposures of less than 5 rad.[5] Growth retardation, microcephaly, and mental retardation are observable at exposures higher than 50 rad.[6] Putting this in perspective involves being aware of the estimated fetal exposure from common radiologic procedures[5] (Table II).

Plain x-rays generally result in fetal exposures in the millirad range. Moreover, x-rays of extremities (ie, humerus, forearm, tibia) allow placement of a lead apron over the patent to further minimize exposure doses. Exposure from CT depends on slice thickness and therefore the number of necessary cuts. Spiral CT has the added dimension of pitch, but, with customary use of pitch higher than or equal to 1, the exposure dose of conventional and spiral CT is the same. It was recently reported that exposure from CT is 1.5 rad but can be reduced to as little as 250 millirad.[7]

Table I. Guidelines for X-Ray Examination or Exposure During Pregnancy

1. Women should be counseled that x-ray exposure from a single diagnostic procedure does not result in harmful fetal effects.
2. Specifically, exposure to less than 5 rad has not been associated with an increase in fetal anomalies or pregnancy loss.
3. Concern about high-dose ionizing radiation exposure should not prevent medically indicated diagnostic x-ray procedures from being performed in pregnancy.
4. Other imaging procedures not associated with ionizing radiation (magnetic resonance imaging, ultrasonography) should be considered instead of x-rays when appropriate, as they are not known to be linked with adverse fetal effects.
5. Use of radioactive isotopes of iodine is contraindicated during pregnancy.
6. Radiopaque and paramagnetic contrast agents are unlikely to cause harm and may be of diagnostic benefit, but these agents should be used only if the potential benefit justifies the potential risk to the fetus.

Data from ACOG Committee on Obstetric Practice. ACOG Committee Opinion. Number 299, September 2004 (replaces No. 158, September 1995). Guidelines for diagnostic imaging during pregnancy. *Obstet Gynecol*. 2004;104(3):647-651.

Table II. Radiation Exposure Doses for Orthopedic X-Rays*

Procedure	Fetal Exposure
Chest x-ray (anteroposterior/lateral)	0.02-0.07 mrad
Abdominal plain x-ray	100 mrad
Hip x-ray (single view)	200 mrad
Head or chest CT	<1 rad
Abdomen and lumbar spine CT	3.5 rad
Pelvis CT	0.25-1.5 rad
Anteroposterior pelvis	0.04 rad
Complete spine series	0.37 rad

*CT, computed tomography.

Data from ACOG Committee on Obstetric Practice. ACOG Committee Opinion. Number 299, September 2004 (replaces No. 158, September 1995). Guidelines for diagnostic imaging during pregnancy. *Obstet Gynecol*. 2004;104(3):647-651. Melnick DM, Wahl W, Dalton VK. Management of general surgical problems in the pregnant patient. *Am J Surg*. 2004;187(2):170-180.

Ultrasound is not a form of ionizing radiation, and magnetic resonance imaging (MRI) uses magnetic radiation instead of ionizing radiation. Also, MRI can safely provide information about abnormalities in the central nervous system initially identified by ultrasound.[8] In orthopedics, nuclear medicine is commonly used in the form of bone scan. In this radiographic test, a chemical is tagged with a radioisotope, and the properties of the radioisotope determine the dose of fetal exposure. Technetium, a commonly used isotope, generally results in an exposure of less than 0.5 rad.[5]

In 1986, Brent[6] suggested that a single x-ray during pregnancy does not warrant a therapeutic abortion. However, the physician-perception study[4] described earlier gives merit to the contention that we as physicians require additional education to accurately counsel our patients.

Leukemia

There has long been debate over the risks of leukemia subtypes after intrauterine exposure to diagnostic radiographic studies. In the 1980s, it was thought that 1 to 2 rad of in utero exposure would increase the incidence of leukemia by a factor of 1.5 to 2.0 over the general population.[6] However, in a study of in utero exposure at Nagasaki—conducted by Burrow and colleagues[9] in 1964—0 of 86 patients developed leukemia even after receiving in utero radiation doses significantly higher than those used in previous studies. This finding was corroborated by larger studies.[10]

More recent literature has found that direct prenatal fetal exposure to x-ray examinations was not associated with a significant overall risk for childhood leukemia, lymphatic leukemia, or myeloid leukemia. Naumburg and colleagues[11] also found little risk variation by trimester of exposure. Furthermore, Ohtaki and colleagues[12] offered that conventional Giemsa staining methods used in the 1960s for detecting translocations have substantially improved over the past 45 years. They studied 331 survivors exposed in utero at Hiroshima and Nagasaki who were born between the day after the nuclear bombing and approximately 9 months later. The finding was that translocation frequency did not increase with dose, with the exception of a less than 1% increase at doses below 0.1 Sv. "Our results," Ohtaki and colleagues wrote, "provide a biologic basis for resolving the long-standing controversy that a substantial risk of childhood leukemia is implicated in human fetuses exposed to low-dose x-rays, whereas animal studies involving mainly high-dose exposures generally do not confirm it."

Safety

Whenever women of reproductive age are being treated, it is important to rule out IUP by obtaining pregnancy tests. Many orthopedic procedures require plain x-rays, CT scans, and intraoperative c-arm fluoroscopy. Each of these modalities has particular safety precautions regarding pregnancy.

C-arm fluoroscopy units are required to have a minimal source-to-end of collimator distance of 12 inches. Also, during c-arm use, the patient–image intensifier distance should be as short as possible to reduce the patient dose. Last, the lead apron should be placed underneath preg-

Table III. Categories of Medication Safety in Pregnancy

A Well-controlled studies show no risk in first trimester; no evidence of risk in later pregnancy.
B Animal and human studies do not show fetal risk; no controlled studies confirm risk in pregnancy; no evidence of risk in later pregnancy.
C Animal studies show adverse fetal effects; no controlled studies in pregnancy.
D Studies show fetal damage; use may be acceptable when conditions threaten woman's life.
X Studies in animals and humans show fetal damage; absolutely contraindicated in pregnancy.

Data from Hart MA. Help! My orthopaedic patient is pregnant! *Orthop Nurs*. 2005;24(2):108-114.

Table IV. Pertinent Risk Factors for Development of Thromboemboli

Pregnancy
Family history
Increased maternal age
Prior deep venous thrombosis
Cesarean section
Thrombophilia

Data from Robertson L, Greer I. Thromboembolism in pregnancy. *Curr Opin Obstet Gynecol*. 2005;17(2):113-116.

nant patients. For plain x-rays, this precaution is achieved by placing the 0.5-mm lead apron on the surface of the abdomen/pelvis. These differences are attributable to the directional source of the ionizing radiation. Direct patient shielding is not typically used in CT because of the rotational nature of the exposure.[13]

Staff Safety

Besides patient concerns, concerns of the orthopedic surgeon and supporting staff of childbearing age must also be considered. In a recent study in Greece, Theocharopoulos and colleagues[14] used an anthropomorphic phantom consisting of a synthetic skeleton embedded in tissue-equivalent materials to calculate pregnancy workloads on the basis of a 2-mSv exposure limit to a gravid abdomen and to correlate embryo dose with the reading of a pregnancy-dedicated dosimeter. Their study, based on treatment of a closed femur fracture, produced valuable results. The authors concluded that scatter radiation during fluoroscopically assisted femur surgery is more pronounced on the side ipsilateral to the operative site. They also stated that fears of occupationally exposed personnel are unjustified if standard 0.5-mm lead-equivalent aprons are worn, and they concluded, "Pregnancy will not inhibit the working career of the staff and does not provide grounds for professional discrimination." Other methods of fetus protection are[14]:

- Moving from treated side to contralateral side results in 13- to 57-fold decrease in exposure.
- Moving 0.5 m cephalad from entry beam reduces surgeon exposure 13-fold.
- Moving 1.5 m away from table reduces exposure by factor of 26 on ipsilateral side and by factor of 6 on contralateral side.
- Exposure is insignificant more than 2 m from source of radiation.

Data from Theocharopoulos N, Damilakis J, Perisinakis K, Papadokostakis G, Hadjipavlou A, Gourtsoyiannis N. Image-guided reconstruction of femoral fractures: is the staff progeny safe? *Clin Orthop*. 2005;(430):182-188.

Anesthesia

Each year, more than 75,000 pregnant women undergo nonobstetric surgery. It is well established that many pregnant women are safely anesthetized daily without adverse effects to fetus or mother.[15] Concerns about operative anesthesia mainly surround teratogenicity of anesthetic agents used. Currently, drug categories are used to determine and label medications with respect to fetal risk[16] (Table IV).

Nearly all anesthetics and analgesics used in pregnancy are category C.[16] Almost all teratogenic medications have the same effect on animals as on humans, which makes animal study results very reliable and applicable. Moreover, anesthetics used in pregnancy are known to cause a variety of physiologic changes, of which the surgeon and the anesthesiologist should be aware.[17] In 1989, reporting on a study of 5405 operations during pregnancy and anesthesia-related outcomes, Mazze and Kallen[18] concluded that the incidence of malformations and stillbirths was not increased in the offspring of women having surgery. However, there was increased incidence of low and very low birthweight infants, and the authors concluded, "Nonobstetric operations during pregnancy are not without hazard." Rosen[19] studied the effects of anesthetic agents on the fetus and concluded that the adverse effects on the fetus are mostly the result of underlying disease and not the agent used.

Positioning and Monitoring Issues

It is well documented that, whenever possible, the patient should be placed on the operative table in lateral decubitus position during the second or third trimester so as to avoid unnecessary compression of the inferior vena cava by the gravid uterus.[20] Other options include placing a wedge under the right hip or tilting the operating table. The need for fetal monitoring is generally answered by gestational age and viability of the fetus. Fetal heart rate (FHR) monitoring can prove useful in identifying intraoperative conditions causing impairment in uteroplacental blood flow and therefore fetal oxygenation.[15] However, many obstetricians feel that intraoperative FHR monitoring has little use because maternal derangements can be assessed and treated without it.[21] Also, it has been shown that no change in fetal outcome has ever been established through intraoperative FHR monitoring.[22]

Consult!

It is useful to consult obstetricians whenever there is uncertainty about these matters and to consistently use a multidisciplinary approach to patient care.

Pain Management

Definitive orthopedic fixation can result in significant postoperative and injury-associated pain. It is common practice to use narcotics and muscle relaxants in the immediate perioperative and postoperative periods to provide comfort to the patient. Naturally, pregnancy raises questions about use of such medications.

Goodman[21] claimed that perioperative opioid use should raise little concern about teratogenicity. The risk for neonate respiratory depression is only pertinent "if delivery occurs at the same time as the surgery." Much of the literature concerning opioids is in the setting of labor pain. A recent systematic review of the literature suggested that epidurals provide better pain relief than systemic medication. However, meperidine (Demerol) is the most commonly used systemic opioid worldwide, and questions still exist about its efficacy and side effect profile. In addition, none of the studies comparing pethidine with other opioids has been convincing.[23]

There are no reports associating muscle relaxants with teratogenicity. The positively charged depolarizing and nondepolarizing agents do not cross the placenta.[22] However, Hart[16] claimed that cyclobenzaprine (Flexeril) is the "only known safe muscle relaxant for use in pregnant women."

Nonsteroidal anti-inflammatory drugs are contraindicated because of their effects on the ductus arteriosus, and they can inhibit labor in the third trimester. From an orthopedic standpoint, they have been repeatedly shown to be deleterious to fracture union. Therefore, acetaminophen is recommended for minor pain relief.

Gestational age plays a major role in determining which medications are safe during each phase of fetal development. It is important to keep in mind that medication risk labels can change during a 9-month pregnancy, depending on the vulnerability of the fetus in any given trimester.[16]

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Anticoagulation

Venous thromboembolic disease consists of deep venous thrombosis (DVT) and pulmonary embolism (PE). Estimated annual incidence in the general population is approximately 0.1%.[24] This percentage is increased 5- to 6-fold in pregnancy, as all 3 components of the Virchow triad can be found in pregnancy.[25] Orthopedic trauma, and subsequent operative intervention, can necessitate varying periods of immobilization. Given the hypercoaguable state of pregnancy, anticoagulation becomes a critical issue. In fact, untreated DVTs have been shown to lead to PEs in 16% of patients and have become the leading cause of maternal death.[26] Important risk factors are listed in Table V.[27]

Choice of anticoagulant is of critical importance in pregnancy. Warfarin is known to cross the placenta and potentially cause fetal bleeding and teratogenicity.[28] Unfractionated heparin (UFH) has been classified a high-alert drug by the Institute for Safe Medicine Practices because of the pharmacologic properties of the agent as well as the risk of medical errors in anticoagulation management using UFH.

"...untreated DVTs have... become the leading cause of maternal death.[26]"

UFH is associated with heparin-induced thrombocytopenia (HIT), bleeding, and osteopenia with long-term therapy.[29] According to a study reported by Hawkins and Evans,[30] 3 of every 100 patients on long-term UFH therapy may experience symptomatic vertebral fractures, and 30% may experience a reduction in bone density leading to osteopenia and/or osteoporosis.

A clear alternative to UFH is low-molecular-weight heparin (LMWH), which is associated with lower incidence of HIT and osteoporosis. It is recommended that LMWH dosing be closely monitored with the assistance of a pharmacist because of volume distribution changes encountered in pregnancy.[31] It is also recommended that treatment be stopped 24 hours before delivery to allow for safe epidural anesthesia and to prevent excessive bleeding.[28]

Another alternative is fondaparinux, a synthetic antithrombotic agent that specifically binds to antithrombin. Fondaparinux has been shown to be as effective as LMWH with respect to anticoagulation and to lack a negative effect on bone.[30]

Last, a more invasive option is temporary placement of inferior vena cava filters. Kawamata and colleagues[32] recently found that use of this practice in 11 patients produced no symptomatic pulmonary thromboembolism during or after pregnancy. All filters were placed suprarenally and removed successfully, and there were no reported complications.

Pelvic and Acetabular Trauma

In 1980, Golan and colleagues[33] examined a series of 15 patients who sustained trauma in late pregnancy. Five of the 15 sustained pelvic fractures, with the most common pattern involving the pubic rami. In this study, fetal outcomes were mixed, with 2 of 5 babies surviving, 2 deaths occurring in utero secondary to placental abruption, and 1 death occurring secondary to uterine rupture. However, of significance is that the 2 live births, though premature, were delivered vaginally without adverse events. Authors of more recent case reports have described open reduction and internal fixation of acetabular fractures in this setting with good outcomes.[34,35] Dunlop and colleagues[36] chronicled

operative treatment of a female 24 weeks pregnant with a comminuted transverse and posterior wall acetabular fracture. The patient suffered no adverse outcomes to the fetus, delivered vaginally at 39 weeks, and was weight-bearing 12 weeks after surgery. However, the authors stated, "While we would not recommend that all pregnant patients with acetabular fractures should undergo open reduction internal fixation, it is an option … that should be offered." Kloen and colleagues[20] also reported that complex acetabular fractures can be treated operatively and uneventfully and result in vaginal childbirth.

In general, all patients should be counseled about the risks and benefits of their surgery. However, in pregnant patients, additional considerations apply.

In a retrospective follow-up of 7 patients with pelvic fractures in pregnancy, Pape and colleagues[37] found that 2 of 3 mothers with surviving fetuses had modifications to the treatment of their pelvic injuries in the interest of fetal well-being. One patient with an anterior column posterior hemitransverse fracture pattern was not eligible for surgery because of coagulopathy induced by amniotic fluid. She was treated nonoperatively and went on to uneventful healing and full weight-bearing. The second patient had multiple orthopedic injuries, including unilateral zone 2 sacrum fractures and ipsilateral anterior pelvic ring fractures. She underwent operative treatment of bilateral open femur fractures, and the pelvic ring injury was treated with an external fixator because of concerns about excessive ionizing radiation. Last, Leggon and colleagues[38] reviewed the literature on pelvic and acetabular fractures (N = 101), found that these injuries were associated with a higher mortality rate among fetuses (35%) than mothers (9%), and concluded that mechanism of injury and injury severity influenced mortality, whereas fracture classification, fracture type, pregnancy trimester, and era of reviewed literature did not correlate with mortality.

Clearly, there are multiple approaches to treating a pregnant patient. Care must be taken to evaluate the well-being of the mother and the fetus to optimize outcomes. Whether to provide operative versus nonoperative treatment of pelvic and acetabular fractures appears to hinge more on injury severity and patient stability than on the nature of the orthopedic injury itself. Loegters and colleagues[39] stated, "Surgical treatment of an unstable fracture of the pelvic ring during pregnancy is possible with a justifiable risk to the mother and child." We add that surgical treatment of these injuries is a reasonable option for pregnant patients to allow for anatomical reduction and increased healing potential while keeping term vaginal delivery as an option.

Conclusions

Treatment of the pregnant orthopedic trauma patient generates many questions and raises many uncertainties in management. After reviewing much of the up-to-date literature, we can recommend a safe approach to orthopedic surgery in the pregnant patient with confidence.

According to our findings, there is minimal radiation risk in obtaining x-rays for operative planning, provided that the cumulative dose is within 5 rad. Also, safety concerns regarding patient positioning and staff radiation exposure should be taken into consideration.

In addition, we found that most anesthetics in pregnancy are category C and therefore safe. Perioperative opioid use for pain management is recommended with little risk. LMWH and fondaparinux are the safest choices for anticoagulation. Last, pregnancy is not a contraindication to operative management of pelvic and acetabular fractures.

It is clear that educating the medical community as well as the patient about the potential risks and misconceptions regarding surgery in pregnancy will decrease the uncertainty and anxiety surrounding this patient population.

Authors' Disclosure Statement

The authors report no actual or potential conflict of interest in relation to this article.

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This paper will be judged for the Resident Writer's Award.