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Musculoskeletal Injuries in Pregnancy

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Background

Musculoskeletal injuries during pregnancy are relatively common. Trauma affects approximately 1 in 12 pregnancies, and it is the leading cause of nonobstetric mortality in pregnant women.[1] Falls are relatively frequent, occurring in about 1 in 4 pregnant women, with multifactorial causes. The majority of hospitalizations occur in the third trimester.[2] Domestic violence is a considerable source of traumatic injuries during pregnancy, with the incidence ranging widely across countries and populations (from 1% to 57%).[3] Motor vehicle accidents (MVAs) are estimated to occur in 207 of 100,000 pregnancies and can cause significant maternal and fetal injury and death, with a mortality rate of 1.4 and 3.7, respectively, per 100,000 pregnancies.[4] Higher crash severity, maternal injury severity, and lack of proper seat belt usage are associated with adverse fetal outcomes.[5] Any of these mechanisms can lead to a wide range of musculoskeletal trauma, including bone and soft tissue injuries.

The physiologic changes of pregnancy lead to unique musculoskeletal injury patterns. The gravid uterus displaces organs and shifts the center of gravity anteriorly (Fig. 1), causing altered biomechanics such as increased lumbar lordosis and anterior pelvic tilt, which can in turn lead to pain and predispose to injuries and falls. The hormonal alterations of pregnancy cause systemic effects on the musculoskeletal system, including increased peripheral and pelvic joint laxity and decreased bone mineralization.[6] These changes can predispose patients to certain musculoskeletal injuries, such as ligament injuries and insufficiency fractures. One study found a positive association between increased parity and finger joint laxity in early pregnancy with the development of back pain during the partum and postpartum period, suggesting that joint laxity is a potential predictor of subsequent pain.[7] Altered biomechanics can also lead to a progressive loss of balance during the course of the pregnancy, which can predispose to injury.[3]

The radiologist plays a key role in the diagnosis of traumatic injuries in pregnant patients, the accuracy of which is crucial for good maternal and fetal outcomes. Any use of imaging should adhere to American College of Radiology (ACR) guidelines, including the “as low as reasonably achievable” principle regarding the use of ionizing radiation. The risks and benefits of imaging for the assessment of pregnant patients should be tailored to each individual case and presentation. A thorough knowledge of injury patterns is important for radiologists participating in the care of pregnant patients.

Imaging Principles in the Pregnant Patient

Pregnant patients present challenging and important diagnostic considerations for radiologists. The ACR guidelines for

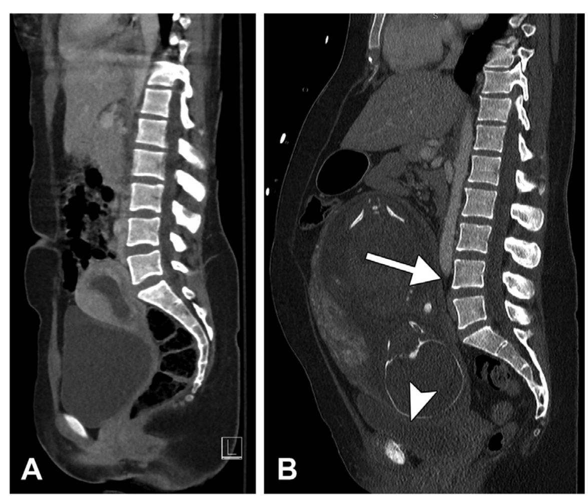

Figure 1 Sagittal CT of a pregnancy at 8 weeks (A) and 28 weeks (B) demonstrates anatomic changes as the conceptus grows. As a pregnancy progresses, the pelvis tilts anteriorly and the gravid uterus expands anteriorly outside the pelvis. The uterus displaces intra-abdominal organs superiorly and results in gradually increasing mass effect on the bladder (arrowhead) and retroperitoneal structures (arrow).

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diagnostic imaging during pregnancy state that ultrasonography and magnetic resonance imaging (MRI) are not associated with increased risk to the mother or fetus, and these modalities should be used prudently with the expectation of answering a specific question. The guidelines also state that modalities that expose the mother and fetus to ionizing radiation, including radiography, computed tomography (CT), fluoroscopy, and nuclear medicine scans, should not be withheld from a pregnant patient if deemed clinically necessary.[8]

Effects of Radiation

The detrimental effects of radiation stem from the formation of free radicals, which damage DNA. This, in turn, can cause cell death, which leads to deterministic effects, namely, effects directly related to the radiation dose received, the severity of effect increasing with the radiation dose. Deterministic effects are seen only above a threshold dose, such as transient skin effects (erythema, epilation, and skin necrosis) above a threshold of 2 Gy.[9] Radiation also causes stochastic, or random effects, that are independent of radiation dose received. Such effects cause alteration of the genetic code or cancer.

An embryo is most sensitive to radiation early in its development due to the high rate of cellular proliferation. Possible deterministic effects at this stage include fetal death (0-2 weeks after fertilization) and teratogenic birth defects such as microcephaly, mental retardation, and organ malformation (2-8 weeks after fertilization). The stochastic effect of increased cancer risk to the fetus is present throughout the pregnancy. The overall risk of teratogenesis is affected by many variables, mainly gestational age and total absorbed dose. These are summarized in Table 1. ACR guidelines note that there are no deterministic effects with cumulative radiation exposure of less than 50 mGy, a level above the range of exposure for diagnostic procedures.[10]

Knowing radiation doses of typical examinations is important for counseling and consenting pregnant patients. Many potential questions and concerns are addressed in the ACR Practice Parameters.[10] As a general rule, the fetus receives approximately one-third the skin entrance dose for radiographic and fluoroscopic procedures.[9] Low fetal dose exams include radiography involving the chest, neck, and extremities as well as CT of the head/neck. Low to moderate fetal dose exams include radiography/fluoroscopy of the abdomen/pelvis and lumbar spine, CT/CTA (computed tomography angiography) of the chest, limited CT of the femoral heads, and nuclear medicine exams. Higher fetal dose exams include CT abdomen/pelvis and whole body PET (positron emission tomography)/CT; these are summarized in Table 2.[11] A

Table 2 Fetal Radiation Doses for Common Radiologic Examinations

Exam Type	Feta Dose (mGy)
Very low-dose examinations (<0.1 mGy)	
Radiography of any extremity, cervical spine	<0.001
Mammography (2 views)	0.001-0.01
Chest radiography (2 views)	0.0005-0.1
Low to moderate dose examinations (0.1-10 mGy)	
Radiography	
Abdominal	3.0
Lumbar	1.0-10
CT	
Head or neck CT	1.0-10
Chest CT or CT pulmonary angiography	0.01-0.66
Limited CT pelvimetry	<1
Nuclear Medicine	
Low-dose perfusion scintigraphy	0.1-0.5
Technetium-99m bone scintigraphy	4-5
Higher dose examinations (10-50 mGy)	
Abdominal CT	1.3-35
Pelvic CT	10-50
^{18}F PET/CT whole-body scintigraphy	10-50

Table adapted from ref. [11].

Table 1 The Effects of Gestational Age and Radiation Dose on Teratogenesis

Gestational Period	Estimated Threshold Dose	Teratogenic Effects
Preimplantation Stage (0-2 weeks postfertilization)	50-100 mGy	Fetal Death (Considered an all-or-none effect. Any nonlethal damage below the threshold dose will be repaired and have no consequence.)
Organogenesis (2-8 weeks after fertilization)	200 mGy	Congenital anomalies/organ malformations (skeleton, eyes, and genitals)
	200-250 mGy	Growth restriction
Fetal Period	Estimated Threshold Dose	Teratogenic Effects
8-15 weeks	60-310 mGy	Severe intellectual disability (high risk)
	200 mGy	Microcephaly
	1,000 mGy +	Intellectual deficit: Estimated 25 IQ point loss per 1000 mGy
16-25 weeks	250-280 mGy	Severe intellectual disability (low risk)

Table adapted from Guidelines for diagnostic imaging during pregnancy and lactation. Committee Opinion No. 723 [published erratum appears in Obstet Gynecol 2018;132:786] ref. [8].

Table 3 Fetal Reduction Techniques by Imaging Modality

Modality	Potential Risk to Fetus	Risk Reduction
"Radiography/ Fluoroscopy	Ionizing radiation	-Use pulsed fluoroscopy -Use low-dose level settings -Use collimation to limit the field of view -Remove the grid -Avoid image magnification
Computed Tomography	Ionizing radiation	-Use low-dose protocol -Decrease the tube potential (kilovolt peak) for small patients -Decrease the tube current-time product (milliampere-second) and use automatic tube current modulation -Increase pitch > 1 -Limit field of view (*Z*-axis coverage) -Avoid multiple phases, if delayed phase is required to evaluate for bladder injury, limit field of view -Use iterative reconstruction algorithms for noise reduction
Magnetic Resonance Imaging	-No reported detrimental effect of MRI - High magnetic field strength with theoretic biologic damage related to cell migration, proliferation, differentiation - Pulsed radiofrequency fields with potential for tissue heating, concern for secondary damage regarding organogenesis - High acoustic noise level, particularly high with fast-acquisition sequences needed for fetal imaging. Concern for damage to fetal ear (esp. after 24 weeks)	-Utilize magnet field strength of 1.5T or less -Limit MRI sequences
Nuclear Medicine	Ionizing radiation	-The fetal doses of diagnostic nuclear medicine are <50 mGy, therefore routine pregnancy screening is not required. -This excludes I-131, which should not be administered during pregnancy.
Ultrasound	-Potential concern of heating and cavitation effects	-Mechanical and thermal indices should be < 1 -Use M-mode instead of color, power, and spectral doppler which require higher intensity acoustic output.

Table compiled from information from: ref. [11].
Wieseler KM, Bhargava P, Kanal KM, Vaidya S, Stewart BK, Dighe MK. Imaging in pregnant patients: examination appropriateness. *Radiographics.* 2010;30(5):1215-1229; discussion 1230-1213.

high dose (10-50 mGy) exam results in the stochastic effect of a 2-fold increase in cancer risk for the child, which is still low in absolute terms (1 in 250).[11]

Intravenous Contrast

Both iodinated contrast media and gadolinium-based contrast agents traverse the placenta, and measurable amounts can be found in the fetus after intravenous administration to the mother. Iodinated contrast agents are FDA category B drugs; reproductive studies in animals demonstrate no risk, but there have not been controlled studies in pregnant women. The main concern with iodinated contrast agents is the effect on the developing fetus's thyroid gland, although multiple studies have shown no adverse effect on neonatal thyroid function from water-soluble iodinated contrast agents.[12] Gadolinium-based contrast agents are classified as FDA category C; animal studies have shown adverse effects, and one large study showed that gadolinium at any point during pregnancy increased the risk of rheumatologic, inflammatory, and infiltrative skin conditions, as well as stillbirth and neonatal death.[13]

Modalities

Ultrasound is the first line modality of choice to assess trauma during pregnancy. A Focused Assessment with Sonography for Trauma scan evaluates the sub-xiphoid, right upper quadrant, left upper quadrant, and supra-pubic regions for maternal pericardial and intraperitoneal fluid. Ultrasound can also be used to assess extremity soft tissues, but it is very limited for the assessment of placental abruption.[14]

Radiography, fluoroscopy, and CT expose the mother and fetus to ionizing radiation, and ordering physicians and radiologists must weigh the risks and benefits of using these modalities to image a pregnant patient. With this in mind,

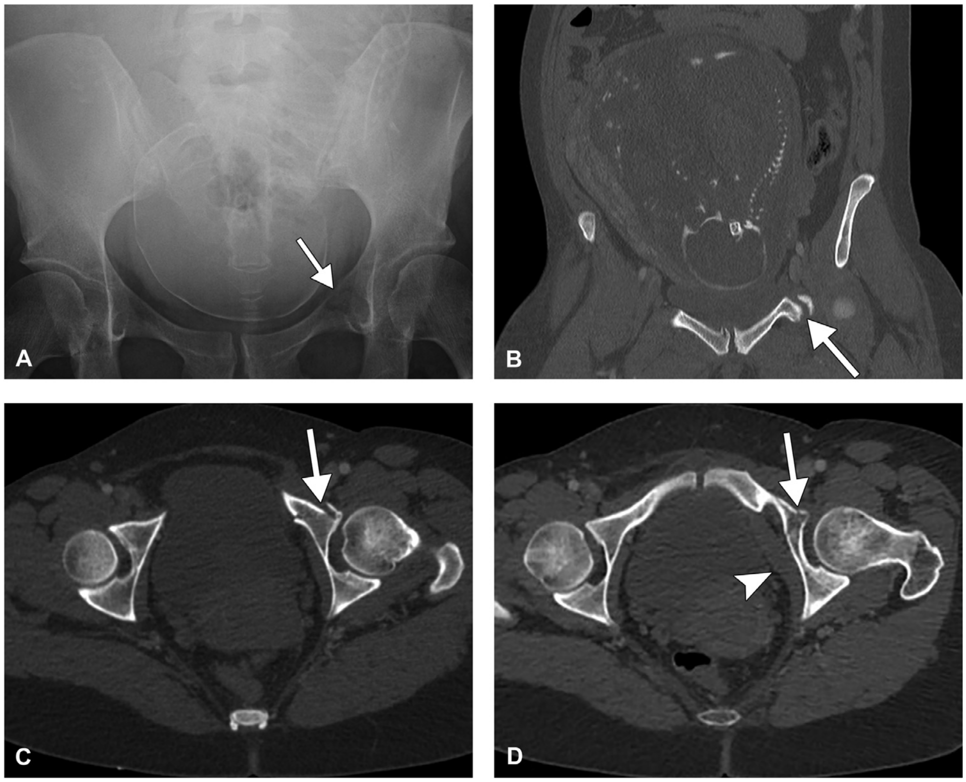

Figure 2 A 29-year-old G2P1 woman at 28 weeks (w) gestation was the driver in a rollover motor vehicle accident. She was unable to ambulate after the accident. AP radiograph (A) demonstrates a nondisplaced left superior pubic ramus fracture (arrow), which is better seen on coronal (B, arrow), and axial (C and D, arrow) CT, where there is a left pelvic side wall hematoma (D, arrowhead).

radiography and CT are sometimes necessary to evaluate maternal musculoskeletal injuries. That said, it is important to limit the area being scanned, use dose reduction techniques and avoid unnecessary or repeat scans when possible. Repeat imaging with multiple CTs may expose the fetus to a radiation dose that exceeds 50 mGy, and in such cases, a medical physicist should be consulted to calculate the fetal dose, and discussion with the patient and referring physician is crucial. Body CT examinations of pregnant patients should be performed with IV iodinated contrast, when possible, as this improves the detection of maternal and fetal/placental and vascular injuries. Oral and/or rectal contrast have no adverse effects or risk to pregnant patients and may be helpful in cases of penetrating trauma in which bowel injury is suspected.[15]

MRI is typically not used to evaluate acute musculoskeletal trauma, due to long acquisition times. However, this is evolving due to the ongoing development of faster imaging techniques and faster MRI protocols for use in the acute setting, for instance, fast hip imaging protocols to assess for acute fracture. MRI can be employed to further characterize spinal, neurologic, or occult osseous and soft tissue injuries. It also has a role in follow-up imaging to reduce overall radiation dose. MRI use is acceptable at any stage of pregnancy if the risk-benefit ratio warrants that the study be performed.[15] In general, gadolinium-based contrast is avoided in MR evaluation of the pregnant patient, however it should not be withheld in the rare circumstance when it is deemed essential for diagnosis. The potential risks of these various imaging modalities as well as strategies to reduce risk are summarized in Table 3.

Traumatic Musculoskeletal Imaging Findings

Fractures, dislocations, ligament and muscle injury are the most common types of injury (in order of frequency), followed by superficial soft tissue injuries, contusions, and crush injuries. Falls are the most common mechanism of injury, followed by MVAs, although MVAs lead to the majority of hospital admissions.[16]

Fractures

With any fracture during pregnancy, assessment of adjacent organs and vasculature must be included in the search pattern (Fig. 2). When rib fractures are present, the radiologist must search for liver, splenic, and renal lacerations (Fig. 3).

Pelvic fractures can be seen with any type of trauma and are especially common after MVAs. In such cases, it is important to assess for placental abruption, hemorrhage, and injury of adjacent vasculature. Focused Assessment with Sonography for Trauma scans can be utilized initially to assess for free fluid in the abdomen or pelvis. Pelvic and acetabular fractures during pregnancy are associated with increased maternal (9%) and fetal (35%) mortality rates, and when

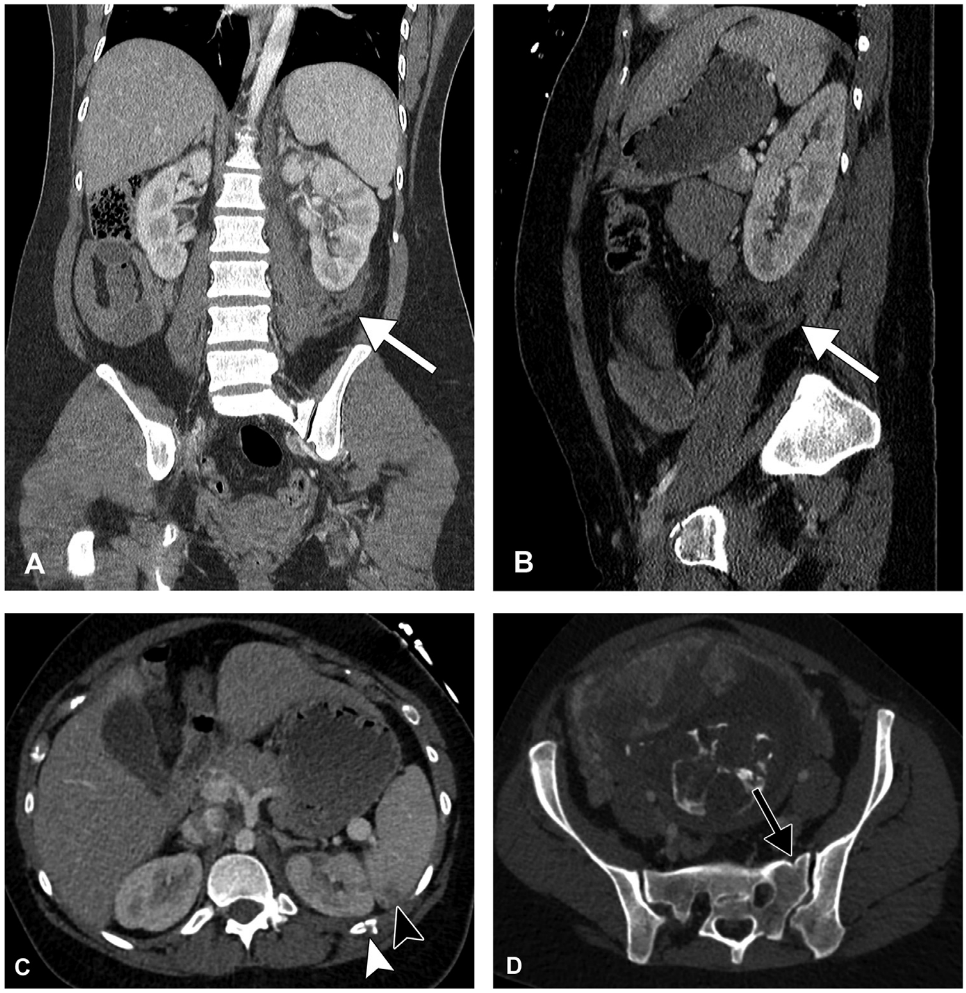

Figure 3 This same 29-year-old G2P1 woman at 28w gestation also had a grade 1 left renal laceration with perinephric hematoma (A and B, white arrows), a left 11th rib fracture (C, white arrowhead) with an associated a grade 1 splenic laceration (C, black arrowhead), and a nondisplaced left sacral fracture (D, black arrow). Note the proximity of the fetal skull to the pelvic fractures. No pelvic vasculature or fetal injuries were sustained.

they occur during the third trimester they are associated with an 18% incidence of fetal skull fracture.[17] A large study done at a level 1 trauma center in Texas found that orthopedic injuries occurred in 6% of pregnant women evaluated for trauma, and when compared to the women who had nonorthopedic injuries, there was significant increased risk of preterm birth before 37 weeks, placental abruption, and perinatal mortality.[18] Both minor and severe orthopedic injuries were associated with increased risk of adverse outcomes, highlighting the need for close monitoring even in those patients with minor injuries.[16]

Nontraumatic pelvic fractures are also an important consideration in pregnancy. Due to increased anterior pelvic tilt of pregnancy, there is increased axial loading of the sacrum and sacroiliac joints. Sacral stress fractures during pregnancy are rare but have been reported, sometimes in conjunction with high levels of physical activity, and might present with buttock pain or lower limb radicular pain.[19] Similarly, patients can develop femoral neck stress fractures (Fig. 4) or pubic stress fractures (Fig. 5), which may be due either to

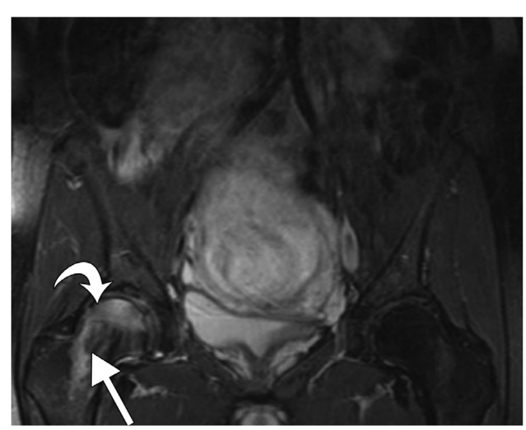

Figure 4 A 31-year-old G2P1 at 22w with severe right hip pain. Coronal STIR MRI shows femoral head edema (curved arrow) that extends into the intertrochanteric region with linear, low signal consistent with a fracture (straight arrow).

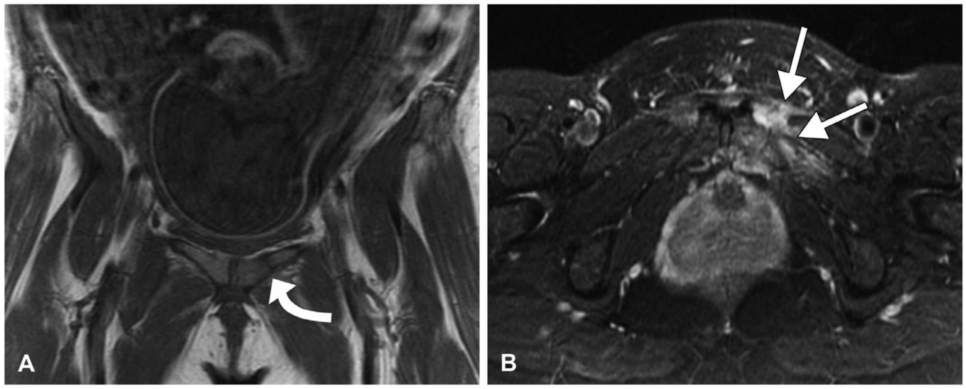

Figure 5 A 32-year-old G3P2 at 35w with anterior pelvic pain. Coronal T1 (A) and axial T2FS (B) MR images show a low signal fracture line (curved arrow) consistent with a fracture and edema of the adjacent soft tissues (straight arrows).

increased load on normal bone, and in some patients, decreased mineralization as well.[20] Intra-partum fractures of the pubic bones and sacrum are possible, and are likely more common than reported; perhaps surprisingly, one study showed pelvic fractures in over half of women with a complicated vaginal delivery, such as with a large fetus or prolonged second stage of labor.[21]

Vertebral fractures, typically compression fractures, also occur during pregnancy and the peripartum period, often at multiple levels.[22] This may be due to increased axial loading with falls and is more common in women with pre-existing low bone mineral density. On MRI, a compression fracture appears as a vertebral body deformity with linear, low signal on T1-weighted images and associated bone marrow edema if acute or subacute. A prevertebral hematoma can be present, and adjacent intervertebral disks can show increased signal.[23] On CT, there can be loss of vertebral body height, with possible retropulsion into the spinal canal.

Metatarsal stress injuries in pregnancy can develop from these same conditions: increased mechanical stress and weight in the setting of decreased bone mineralization and/or osteopenia. Radiographs can show periosteal reaction along the metatarsal shaft, possibly with a fracture lucency. MRI will show bone marrow and/or periosteal edema in a stress reaction, with additional linear, low signal in the setting of a fracture.

Pubic Symphyseal Injury

The pubic symphysis is a nonsynovial joint separated by a fibrocartilaginous disc and reinforced by 4 pubic ligaments.[24] The normal pubic symphysis measures 4-5 mm on radiographs, which can increase by 1-3 mm in the pregnant patient (Fig. 6) but should return to normal within 4-6 months of delivery. Pregnancy and/or birth injury can cause pubic diastasis of > 10 mm (Fig. 7) or pubic symphyseal rupture (>25 mm).[24] A very wide pubic separation (>40 mm) is also associated with rupture of the sacroiliac joint and pelvic ring instability, which necessitates surgical fixation.[25]

Pubic bone marrow edema (Fig. 8) can normally be seen in up to 3 of 4 pregnant women on MRI, and this may be

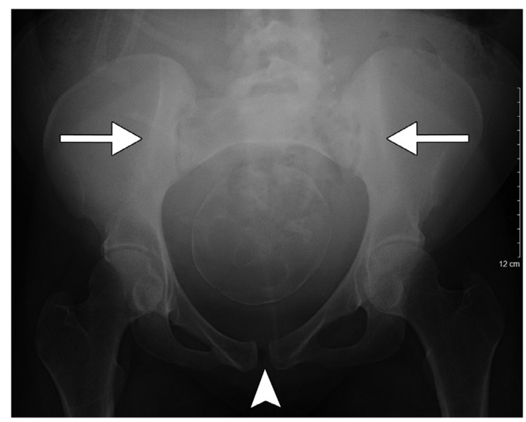

Figure 6 AP pelvic radiograph of a 29-year-old G7P5 at 30w1d who presented after a fall backwards down some stairs while carrying a small dresser. There is mild pubic symphysis diastasis at 8 mm (arrowhead) and triangular-shaped, bilateral sclerosis of the iliac portions of the sacroiliac joints, most consistent with osteitis condensans ilii (arrows). The fetal skeletal structures are faintly visualized.

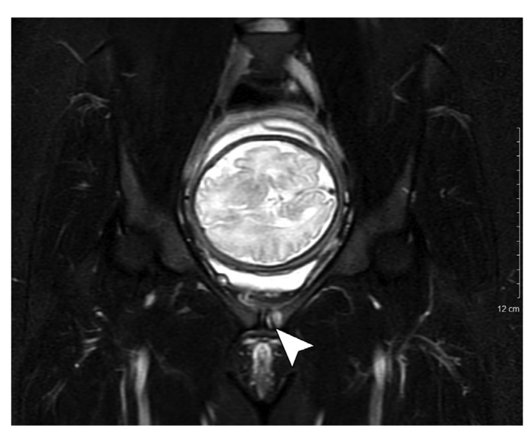

Figure 8 Coronal STIR MRI of a 21-year-old G1P0 patient at 34w demonstrates edema of the left superior pubic ramus with low signal fracture line (arrow), compatible with stress fracture.

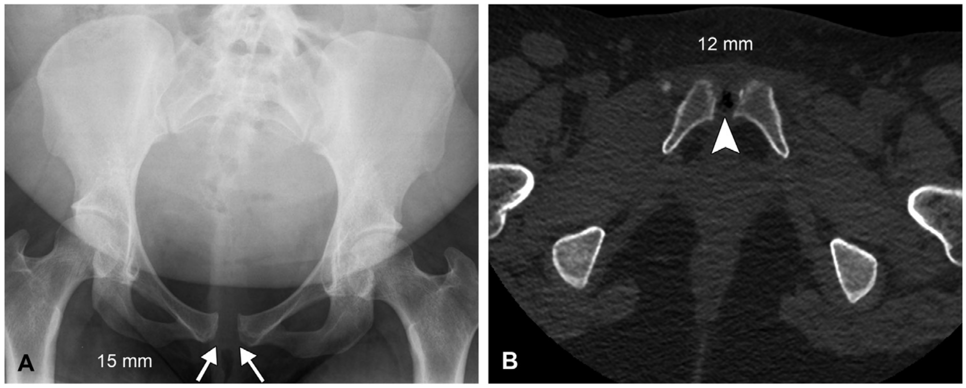

Figure 7 AP pelvic radiograph (A) and axial CT (B) on 2 different patients demonstrates pubic symphysis diastasis (A, short arrows, and B, arrowhead). Measurements of pubic symphyseal widening are classically taken on the AP pelvic radiograph and measured at the narrowest point. The CT also shows vacuum phenomenon (B, arrowhead) at the area of diastasis.

associated with pain.[24] This condition is often referred to as osteitis pubis, and it is thought to be a stress-type injury. Radiographs can show parasymphyseal sclerosis, osteophyte formation, and cortical irregularity.[26] Some postpartum athletes who had osteitis pubis before pregnancy can have a severe onset of pain after returning to their sport.[27] Osteitis pubis is usually managed clinically, although radiographs are helpful for evaluation if there is suspicion of true diastasis and/or rupture. MRI can be helpful to assess patients with pain that does not resolve in the postpartum period, as some patients will have occult pelvic fractures from childbirth.

Lower Extremity Injury

Injuries involving the lower extremities are the most commonly encountered musculoskeletal finding during pregnancy. Ankle sprains are common in pregnancy due to falls and altered balance due to the gravid uterus. These can usually be managed conservatively, often without imaging. Depending on presentation, radiographs (Fig. 9) are used to evaluate for fracture, and ultrasound is an excellent method to evaluate for ligamentous injury. If there is a displaced fracture or concern for ligamentous injury, the ankle can be further imaged with CT or MRI. The indications for orthopedic surgery do not change in pregnancy. The many measures required to protect the fetus from the effects of anesthesia, the surgery itself, and intra-operative radiation are beyond the scope of this paper.[28]

Nontraumatic Musculoskeletal Imaging Findings

Pregnant or postpartum patients may present with nonspecific, atraumatic musculoskeletal pain, which in some cases

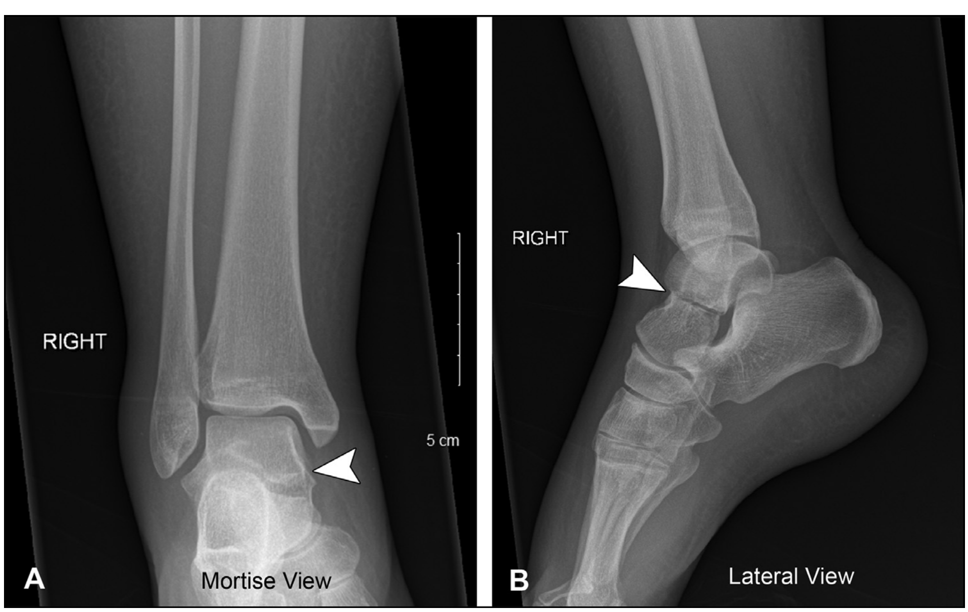

Figure 9 A 25-year-old G1P0 woman at 34w, was a restrained driver in a motor vehicle crash. The car was going 70 mph and hit a guardrail. AP (A) and lateral (B) radiographs show a nondisplaced talar neck fracture (arrowheads). This patient underwent successful operative fixation.

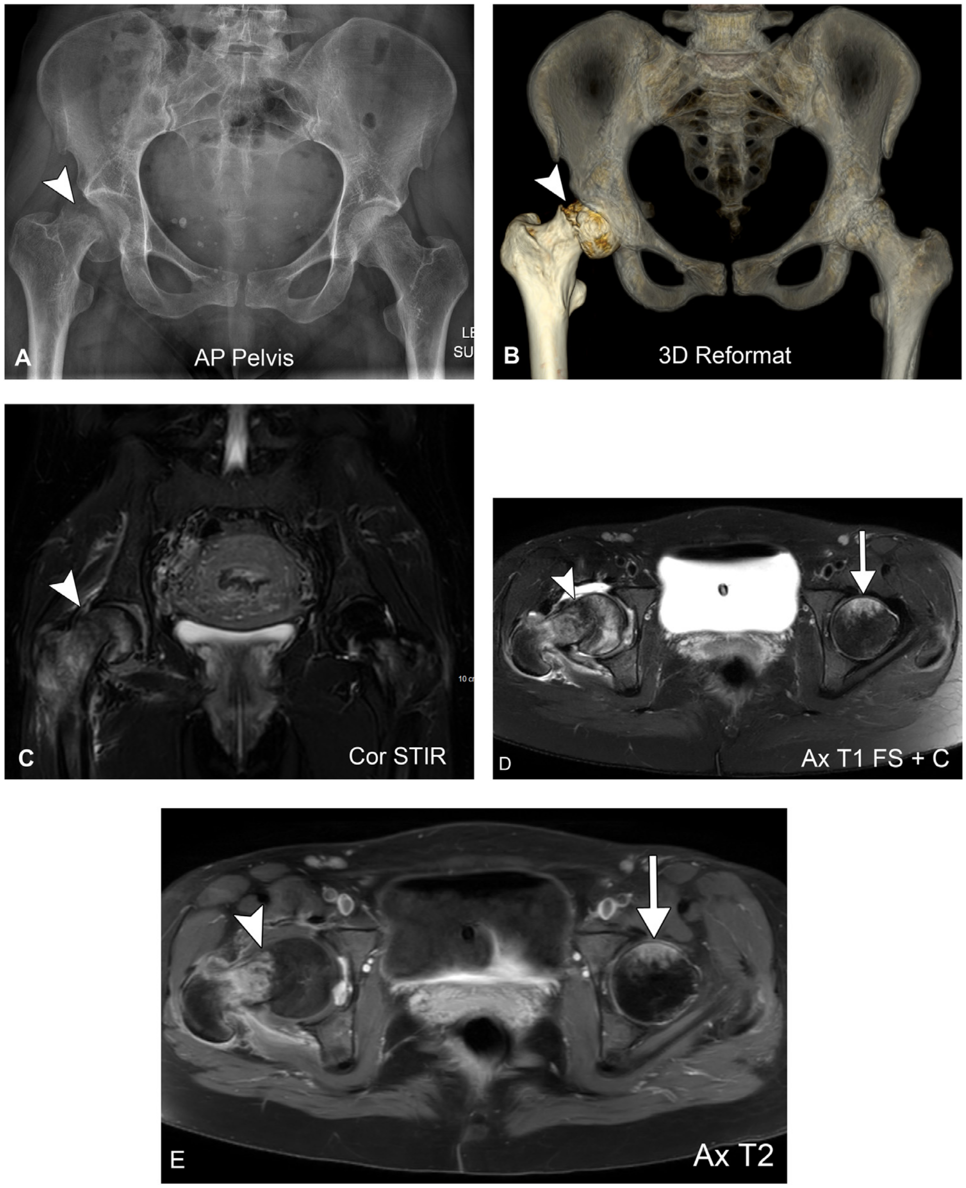

Figure 10 During the last trimester of her pregnancy, this 33-year-old woman had a 1-month history of hip pain, attributed to sciatica. She presented to the ER 9 days after delivery with sudden onset severe right hip pain and inability to bear weight. She was found to have a right subcapital femoral neck fracture (arrowhead) on AP pelvic radiograph (A) and coronal reconstructed 3D CT image (B). The lack of trauma prompted an MRI to exclude pathologic fracture, but no pathologic lesion was present. MR Coronal STIR (C), axial T1 fat saturated with contrast (D) and axial T2 with fat saturation (E) images showed the right hip fracture (arrowheads). In addition, there was marrow edema of the left femoral head/neck (arrows), without fracture, consistent with transient osteoporosis of pregnancy.

will require imaging. Some common conditions are discussed below.

Osseous Injuries

Idiopathic transient osteoporosis of pregnancy is a rare, self-limiting condition of skeletal fragility characterized by acute pain with the development of localized osteoporosis in peri-articular bone. There are 3 stages: Stage 1 is progressive discomfort over weeks; Stage 2 is significant calcium demineralization measured on bone densitometry and is most likely to occur during the third trimester when 80% of the fetal skeleton is mineralized. Stage 3 occurs when the symptoms of transient osteoporosis of pregnancy resolve, usually after delivery.[29]

This condition most commonly affects the proximal femurs, left more often than right, in pregnant women in the third trimester (often called "TOH" for transient osteoporosis of the hip). Although idiopathic, some studies suggest the initial insult may result from ischemia. The osteopenia/radiolucency is apparent on radiographs, and dual-energy X-ray absorptiometry is notable for low bone mineral density, while the lumbar spine bone mineral density may be normal. On MRI, the femoral head and neck are diffusely edematous, and it is unclear if this results from true demineralization versus artifact from increased water content.[30] Due to these

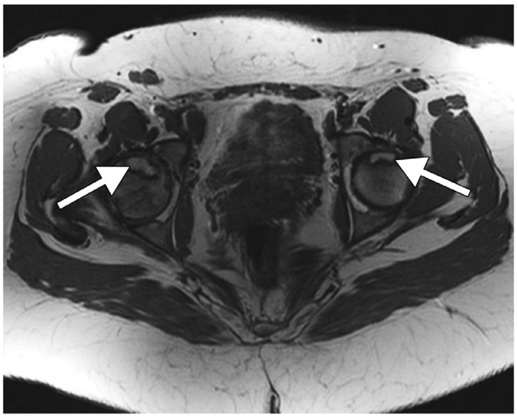

Figure 11 A 31-year-old G1P0 at 22w with bilateral hip pain. Axial T1 MRI shows bilateral geographic, linear low signal (arrows) with central fat signal, consistent with avascular necrosis.

physiologic changes, the femoral neck is fragile and prone to fracture with minimal or no trauma (Fig. 10). Therefore, persistent or severe hip pain or inability to bear weight in a pregnant patient should prompt further investigation with imaging.

There have been several cases reported in the literature of atraumatic bilateral femoral neck fracture in pregnant patients.[31,32] If diagnosed early, the patient may be able to undergo reduction with cannulated screw fixation. However, if diagnosis is delayed for fear of radiation or otherwise, the patient may require a bipolar hemiarthroplasty due to osseous resorption at the fracture site.[31]

Femoral head osteonecrosis is caused by a variety of etiologies and may affect the proximal femur during pregnancy. Although rare, multiple cases have been reported in the literature, and the condition seems more likely to occur in older, primigravid women. The etiology is unknown and likely multifactorial, including venous congestion, hypercoagulability, altered biomechanics, and in some cases, a sequela of ovarian hyperstimulation medication.[33] There is an increased risk for both deep venous thrombosis and femoral head osteonecrosis on the left side more than the right, with the left accounting for 88% of cases, suggesting a possible venous congestion etiology.[34] Osteonecrosis (Fig. 11) can be distinguished from TOH on MRI by several findings including: femoral head deformity, double-line sign with edema on T2-weighted images, low signal subchondral area at least 4 mm thick.[35] Radiographs may show the crescent sign (subchondral radiolucency), geographic sclerosis, or subchondral fracture and progressive femoral head collapse.[34] Treatment is controversial and includes restricted weight bearing, core decompression, and/or use of a vascularized structural graft.

Neuropathies and Regional Pain

Back/pelvic pain

Low back pain and pelvic girdle pain are common during pregnancy and may affect up to 71% and 65% of women,

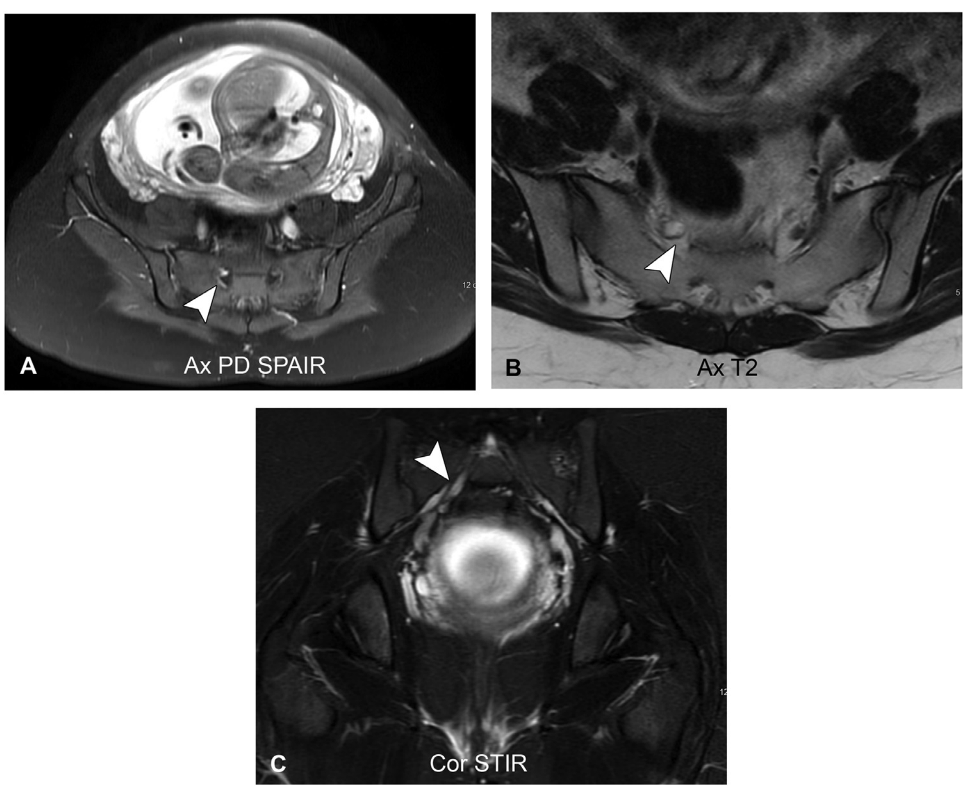

Figure 12 A 21-year-old G1P0 woman at 34w presented with acute onset lower back and hip pain, and new onset right foot drop as well as right leg numbness. MRI (a-c) revealed a thickened, edematous right S1 nerve root (arrowheads) seen on fluid-sensitive sequences. There is mass effect from the gravid uterus on the psoas muscles, common iliac vessels, and exiting nerve roots of the lower lumbar and sacral spine.

respectively, toward the end of pregnancy.[36] Contributing factors may include exaggerated lumbar lordosis, anterior pelvic tilt, and mechanical strain resulting in increased loading on the sacrum and sacroiliac joints, altered gait, pelvic ligamentous laxity, and neurovascular compression. The diagnosis is usually clinical, although in cases of severe pain, lumbosacral radiculopathy, or suspected cauda equina syndrome, MRI may be performed.

Neuropathy

Neuropathy is not uncommon during pregnancy or the postpartum period. The L5 and S1 nerve roots may be compressed by the gravid uterus and can appear swollen with high signal on fluid-sensitive sequences and postcontrast enhancement (Fig. 12), resulting in sciatica and or foot drop.[37] Meralgia paresthetica is compression of the lateral femoral cutaneous nerve by the inguinal ligament, leading to sensory neuropathy of the lateral thigh.[37,38] The lateral femoral cutaneous nerve can be identified with US, on which the nerve can appear enlarged with hypoechoic nerve fascicles. Intercostal neuralgia is also associated with pregnancy, which generally resolves after delivery and is likely due to compression.

Carpal tunnel syndrome

There is an increased occurrence of signs and symptoms of mild carpal tunnel syndrome (CTS) during the third trimester of pregnancy.[39] CTS is caused by compression of the median nerve as it traverses the carpal tunnel, resulting in numbness, tingling, weakness of the thenar muscles and the radial aspect of the hand, with decreased grip strength. CTS may manifest on MSK ultrasound as an enlarged, hypoechoic median nerve, with a difference of 2 mm^2 in cross-sectional area when comparing the proximal (at pronator quadratus) and distal (at carpal tunnel) transverse areas of the median nerve.[40] The MRI features include high T2/STIR signal with enlargement of the median nerve proximally within the carpal tunnel (at the level of the pisiform) and flattening of the nerve distally (at the level of the hamate), with bowing of the flexor retinaculum.[41]

Soft Tissue Injuries

Diastasis recti

Diastasis of the rectus abdominis muscles is defined as a gap >25 mm between the 2 muscle bellies, and it may be seen in up to 50% of pregnant women.[42] This may or may not resolve in the postpartum period, and unresolved diastasis can cause pain and weakness. Ultrasound is useful for evaluation, especially in the postpartum period. Targeted physical therapy is useful in many cases, with surgical repair a last resort for unresolved, symptomatic cases.

De Quervain tenosynovitis

De Quervain tenosynovitis can occur in new mothers within the first 3 months of delivery, due to overuse from repeatedly lifting an infant.[43] Repetitive microtrauma cause painful swelling of the abductor pollicis longus and extensor pollicis brevis tendons, which comprise the first extensor compartment of the wrist. Imaging findings on US include hypoechoic fluid in the tendon sheath with synovial thickening, with or without hyperemia on color Doppler evaluation. The tendons are also usually thickened and hypoechoic. On MRI, the tendons may appear thickened and abnormal in signal, with hyperintense fluid or synovium distending the tendon sheaths.

Conclusion

Trauma in the pregnant patient can result in injury to and/or death of the mother or fetus. Physiologic changes of pregnancy can predispose to certain types of nontraumatic musculoskeletal injuries, and musculoskeletal trauma can lead to serious complications due to the location of the gravid uterus. Imaging can be essential to diagnosis, but there are numerous considerations when selecting the appropriate imaging study and contrast material. Radiologists should be aware of the imaging findings of musculoskeletal injuries and trauma during pregnancy, as well as the risks, benefits, and guidelines of the use of diagnostic imaging in pregnant patients.

References

1. Hill CC, Pickinpaugh J: Trauma and surgical emergencies in the obstetric patient. Surg Clin North Am 88:421-440, 2008.. viii
2. Dunning K, LeMasters G, Bhattacharya A: A major public health issue: The high incidence of falls during pregnancy. Matern Child Health J 14:720-725, 2010
3. Mendez-Figueroa H, Dahlke JD, Vrees RA, et al: Trauma in pregnancy: An updated systematic review. Am J Obstet Gynecol 209:1-10, 2013
4. Kvarnstrand L, Milsom I, Lekander T, et al: Maternal fatalities, fetal and neonatal deaths related to motor vehicle crashes during pregnancy: A national population-based study. Acta Obstet Gynecol Scand 87:946-952, 2008
5. Lucia A, Dantoni SE: Trauma management of the pregnant patient. Crit Care Clin 32:109-117, 2016
6. Marnach ML, Ramin KD, Ramsey PS, et al: Characterization of the relationship between joint laxity and maternal hormones in pregnancy. Obstet Gynecol 101:331-335, 2003
7. Lindgren A, Kristiansson P: Finger joint laxity, number of previous pregnancies and pregnancy induced back pain in a cohort study. BMC Pregnancy Childbirth 14:61, 2014
8. American College of Obstetrics and Gynecology Committee on Obstetric Practice: ACOG Committee Opinion No. 723: Guidelines for diagnostic imaging during pregnancy and lactation. Obstet Gynecol 130: e210-e216, 2017
9. Dighe M, Moirano J. In: Abujudeh H, Bruno M, eds. *Radiology Noninterpretive Skills: The Requisites*. Philadephia, PA: Elsevier, Inc.
10. ACR−SPR Practice Parameter For Imaging Pregnant Or Potentially Pregnant Adolescents And Women With Ionizing Radiation. ACR. American College of Radiology, Published 2018 Web site https://www.acr.org/-/media/ACR/Files/Practice-Parameters/Pregnant-Pts.pdf?la=en Accessed February 28, 2020, Resolution 39
11. Tremblay E, Therasse E, Thomassin-Naggara I, et al: Quality initiatives: Guidelines for use of medical imaging during pregnancy and lactation. Radiographics 32:897-911, 2012
12. ACR Committee on Drugs and Contrast Media: ACR Manual on Contrast Media. American College of Radiology, 2020
13. Ray JG, Vermeulen MJ, Bharatha A, Montanera WJ, Park AL: Association between MRI exposure during pregnancy and fetal and childhood outcomes. JAMA 316:952-961, 2016

14. Kopelman TR, Berardoni NE, Manriquez M, et al: The ability of computed tomography to diagnose placental abruption in the trauma patient. J Trauma Acute Care Surg 74:236-241, 2013
15. Raptis CA, Mellnick VM, Raptis DA, et al: Imaging of trauma in the pregnant patient. Radiographics 34:748-763, 2014
16. El-Kady D, Gilbert WM, Anderson J, et al: Trauma during pregnancy: An analysis of maternal and fetal outcomes in a large population. Am J Obstet Gynecol 190:1661-1668, 2004
17. Leggon RE, Wood GC, Indeck MC: Pelvic fractures in pregnancy: Factors influencing maternal and fetal outcomes. J Trauma 53:796-804, 2002
18. Cannada LK, Pan P, Casey BM, et al: Pregnancy outcomes after orthopedic trauma. J Trauma 69:694-698, 2010.. discussion 698
19. Rousiere M, Kahan A, Job-Deslandre C: Postpartal sacral fracture without osteoporosis. Joint Bone Spine 68:71-73, 2001
20. Mikawa Y, Watanabe R, Yamano Y, et al: Stress fracture of the body of pubis in a pregnant woman. Case report. Arch Orthop Trauma Surg 107:193-194, 1988
21. Brandon C, Jacobson JA, Low LK, et al: Pubic bone injuries in primiparous women: Magnetic resonance imaging in detection and differential diagnosis of structural injury. Ultrasound Obstet Gynecol 39:444-451, 2012
22. Vassalou EE, Klontzas ME, Tsifountoudis IP, et al: Spectrum of skeletal disorders during the peripartum period: MRI patterns. Diagn Interv Radiol 25:245-250, 2019
23. Fujiwara T, Akeda K, Yamada J, et al: Endplate and intervertebral disc injuries in acute and single level osteoporotic vertebral fractures: Is there any association with the process of bone healing. BMC Musculoskelet Disord 20:336, 2019
24. Agten CA, Metzler C, Rosskopf AB, et al: MR imaging of pubic symphysis after uncomplicated vaginal delivery and planned caesarean delivery in the first postpartum week. Clin Imaging 56:58-62, 2019
25. Yoo JJ, Ha YC, Lee YK, et al: Incidence and risk factors of symptomatic peripartum diastasis of pubic symphysis. J Korean Med Sci 29:281-286, 2014
26. Budak MJ, Oliver TB: There's a hole in my symphysis — A review of disorders causing widening, erosion, and destruction of the symphysis pubis. Clin Radiol 68:173-180, 2013
27. Khan W, Zoga AC, Meyers WC: Magnetic resonance imaging of athletic pubalgia and the sports hernia: Current understanding and practice. Magn Reson Imaging Clin N Am 21:97-110, 2013
28. Flik K, Kloen P, Toro JB, et al: Orthopaedic trauma in the pregnant patient. J Am Acad Orthop Surg 14:175-182, 2006
29. Vester H, Seifert-Klauss V, van Griensven M, et al: Fractures due to transient osteoporosis of pregnancy. Int J Gynaecol Obstet 124:259-260, 2014
30. Kovacs CS: Maternal mineral and bone metabolism during pregnancy, lactation, and post-weaning recovery. Physiol Rev 96:449-547, 2016
31. Emami MJ, Abdollahpour HR, Kazemi AR, et al: Bilateral subcapital femoral neck fractures secondary to transient osteoporosis during pregnancy: A case report. J Orthop Surg (Hong Kong) 20:260-262, 2012
32. Kasahara K, Kita N, Kawasaki T, et al: Bilateral femoral neck fractures resulting from pregnancy-associated osteoporosis showed bone marrow edema on magnetic resonance imaging. J Obstet Gynaecol Res 43:1067-1070, 2017
33. Vandenbussche E, Madhar M, Nich C, et al: Bilateral osteonecrosis of the femoral head after pregnancy. Arch Orthop Trauma Surg 125:201-203, 2005
34. Montella BJ, Nunley JA, Urbaniak JR: Osteonecrosis of the femoral head associated with pregnancy. A preliminary report. J Bone Joint Surg Am 81:790-798, 1999
35. Asadipooya K, Graves L, Greene LW: Transient osteoporosis of the hip: Review of the literature. Osteoporos Int 28:1805-1816, 2017
36. Casagrande D, Gugala Z, Clark SM, et al: Low back pain and pelvic girdle pain in pregnancy. J Am Acad Orthop Surg 23:539-549, 2015
37. Sax TW, Rosenbaum RB: Neuromuscular disorders in pregnancy. Muscle Nerve 34:559-571, 2006
38. Greene J, Feldman D: Chapter 7: Pregnancy. In: Browner BD, Fuller RP (eds): Musculoskeletal Emergencies, Philadelphia, PA: Saunders, an imprint of Elsevier Inc, 59-63, 2013
39. Oliveira GAD, Bernardes JM, Santos ES, et al: Carpal tunnel syndrome during the third trimester of pregnancy: Prevalence and risk factors. Arch Gynecol Obstet 300:623-631, 2019
40. Jacobson JA: Fundamentals of Musculoskeletal Ultrasound. (Edition 3. ed). Philadelphia, PA: Elsevier, 2018
41. Dong Q, Jacobson JA, Jamadar DA, et al: Entrapment neuropathies in the upper and lower limbs: Anatomy and MRI features. Radiol Res Pract 2012:230679, 2012
42. Thabah M, Ravindran V: Musculoskeletal problems in pregnancy. Rheumatol Int 35:581-587, 2015
43. Anderson SE, Steinbach LS, De Monaco D, et al: Baby wrist": MRI of an overuse syndrome in mothers.. AJR Am J Roentgenol 182:719-724, 2004