Introduction
Pregnancy-induced hormonal and physical changes increase the risk of musculoskeletal problems. Stress on the axial skeleton, pelvic girdle, and genital tract may lead to acute disorders, including nonspecific pain, neurologic compression, joint disruption, and septic arthritis.

The purpose of this review is to illustrate imaging characteristics of the main musculoskeletal pelvic disorders during pregnancy, labor, and postpartum.

Low back and pelvic girdle pain
Low back and pelvic pain are the most frequent pregnancy-related musculoskeletal symptoms. They may occur during pregnancy (45%) and the postpartum period (25%), but their severity requires medical attention in only 25% and 5% of cases, respectively [1].

Isolated low back pain occurs in 24% to 90% of cases [1–2]. It also occurs approximately twice as often in women who have had back pain before becoming pregnant and more often in women who have previously been pregnant [2].

Pelvic girdle pain (PGP) specifically indicates pregnancy-related pain in the lumbosacral, sacroiliac, and pubic symphysis joints [3]. Twenty-two percent of all women experience PGP during pregnancy, labor, or postpartum, 5–8% of those with severe symptoms and disability. In addition, PGP may be observed in 7% of women after delivery [3–4].

Several risk factors for PGP have been identified, such as possible genetic predisposition, multiparity, a previous history of pelvic trauma, raised body mass index, elevated relaxin hormone levels, asymmetrical laxity of the sacroiliac joint, abnormal pelvic girdle biomechanics, excessive abduction in labor, strenuous work during pregnancy, and hypermobility of the joints [5]. The diagnosis is usually based on clinical examination. Imaging is infrequently used [3].

Radiographs, ultrasound (US), and magnetic resonance imaging (MRI) may only be helpful in cases with severe or unusual symptoms. US is useful in the assessment of joint diastasis and can be safely repeated for follow-up; whereas MRI is useful to assess the lumbar spine [2–3].

Transient osteoporosis of the hip
Transient osteoporosis of the hip (TOH) is a rare disorder of unknown etiology that typically occurs during the third trimester of pregnancy; it involves primiparas in two-thirds of cases [6]. One-third of all TOH occur in pregnancy or early postpartum [6]. Bilateral involvement is observed in one-third of cases [1].

TOH is characterized by sudden or gradual onset intense hip pain preventing gait, persisting at rest, and worsening when bearing weight, without hip limitation on clinical examination. Clinical symptoms may begin before the third trimester of pregnancy or after delivery and may easily and incorrectly be attributed to pelvic instability [6].

Radiographs show marked unilateral or bilateral lucency of the femoral head and neck with preservation of the joint space [2–3].

MRI typically shows diffuse low T1-weighted and high T2-weighted signal intensity of the femoral head and neck extending to the trochanteric region with occasional joint effusion or capsular thickening (Figures 1 and 2) [6]. Abnormalities are usually observed within 48 hours after the onset of symptoms and spontaneously resolve within 6–8 months [3].

Continued unprotected weight-bearing in patients with TOH can result in a fracture of the femoral head; therefore, early diagnosis is important to prevent possible complications [2]. MRI is highly sensitive for the diagnosis of occult hip fracture and allows reliable distinction between osteonecrosis and transient osteoporosis.

SHORT ABSTRACT
Pelvic Musculoskeletal Disorders Related to Pregnancy
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Stress on the axial skeleton and pelvic rim during childbearing and childbirth may lead to acute disorders, including pain, neurologic compression, joint disruption, and hematogenous infections. Pregnancy causes biomechanical changes that may lead to a wide spectrum of pelvic musculoskeletal disorders with morphologic changes on imaging that require detailed understanding and accurate diagnosis by radiologists. The purpose of this review is to illustrate the main features of these disorders and to discuss the role of imaging.

Keywords: Musculoskeletal imaging; Postpartum; Pregnancy
Recurrence of TOH in later pregnancies is rare [3].

Osteonecrosis of the femoral head
Pregnancy-related avascular necrosis of the femoral head, first reported by Pfeifer in 1957, is an uncommon disorder and usually occurs in the third trimester of pregnancy or in the early postpartum [3]. Femoral head osteonecrosis related to pregnancy is usually unilateral and affects the left hip, in comparison with idiopathic osteonecrosis in nonpregnant women. Relatively older mothers are most frequently involved [3, 7].

The exact etiology is unknown, but several factors may act together to produce insufficiency of blood supply to the femoral head, such as an increase in the level of unbound maternal cortisol at the end of pregnancy, high levels of estrogen and progesterone, increased interosseous pressure, or direct injury through compression by the growing uterus or during a difficult delivery [3].

The symptoms usually begin in the third trimester, with deep, increasing pain of variable severity of the groin exaggerated by standing and walking and radiating to the knee, the thigh, or the back [2, 3]. Radiographs are usually normal in the early stages. In the later stages of the disease, they reveal sclerosis, mottled subchondral radiolucency (the crescent sign), and eventually collapse of the femoral head (Figure 3) [2].

High clinical suspicion and use of MRI allow an earlier diagnosis and a better prognosis [3]. MRI typically shows a well-demarcated focal lesion in the subchondral region of low T1-weighted or low to intermediate T2-weighted signal intensity [3, 8]. The infarction zone is delineated by a serpiginous line of demarcation extending to the subchondral bone on both sides with a "double-line sign" (low-intensity centrality surrounded by a high-intensity perimeter) which is pathognomonic for osteonecrosis [1, 8].

MRI is probably the only noninvasive way to distinguish early osteonecrosis from TOH. This distinction is
important because the outcome of these diseases is different: TOH is a self-limiting disease; whereas osteonecrosis may be progressive and lead to collapse of the articular surface with secondary degenerative joint disease.

**Osteoporosis and stress fractures**

Pregnancy and lactation-related osteoporosis is a rare but probably underestimated figure with an unclear pathogenesis. It has been shown that the bone mineral density (BMD) decreases during pregnancy and continues after delivery when breastfeeding. Decreased serum calcium levels may occur during pregnancy due to decreased levels of 1,25-dihydroxyvitamin D3, decreased calcitonin levels, and the effects of cytokines on bone remodeling [9].

However, occurrence of true osteoporosis in pregnancy and peripartum remains unusual [1]. Poor general nutrition, low calcium intake, and a positive family history of osteoporosis as well as hormonal change, pregnancy-related stress, inherited collagen synthesis defect, neural mechanisms, and vascular mechanisms appear to be strong risk factors for pregnancy- and lactation-associated osteoporosis and stress fractures [3].

Pelvic and hip stress fractures may occur during pregnancy or immediately postpartum. Stress fracture is a general term that includes both fatigue fractures occurring in a normal bone exposed to overload and insufficiency fractures occurring in weakened bone withstandings a normal biomechanical load [1, 9].

Sacral fractures occurring during pregnancy, labor, or immediate postpartum are rare. Only a few case reports have been published in the English-language literature of patients presenting with insufficiency fractures, fatigue fractures, or fractures of undetermined pathogenesis [9, 10]. Risk factors for fatigue sacral fractures during pregnancy and postpartum include vaginal delivery of a high birth weight infant, increased lumbar lordosis, excessive weight gain, and rapid vaginal delivery [9].

Imaging findings of pregnancy-related sacral fractures are similar to sacral insufficiency fractures. Radiographs may be normal or demonstrate unilateral or bilateral areas of sclerosis along the sacral wings [9]. MRI typically shows fractures as thin lines of low T1-weighted and T2-weighted signal intensity lying 1–2 cm parallel to the sacroiliac joint and surrounded by bone marrow edema [9].

Computed tomography (CT) demonstrates increased density along the sacral alae representing the reactive sclerosis along the fracture lines (Figure 5). Dual-energy X-ray absorptiometry may be useful in assessing decreased BMD T-scores in the lumbar spine and femoral neck [9].

The clinical differential diagnoses include sacroilitis with inflammatory or infectious causes, osteitis condensans ili, lumbosacral degenerative spondylitis, and transient regional osteoporosis of the sacrum [9].

Stress fractures of the femoral head appear as an important cause of pregnancy-related hip disease. These fractures are usually located on the anterior and superior aspect of the femoral head, an area of maximum load during gait.

Clinical features share many similarities with TOH, but careful examination of MRI can differentiate them. This
diagnosis is important because it might reveal an underlying bone disease [6].

On MRI, subchondral bone fractures specifically appear as low signal intensity curvilinear lines or bands lying parallel to the subchondral bone and surrounded by edema [1].

CT also allows demonstration of the fracture line (Figure 6) as a thin hypodense line of the subchondral bone with dense margins.

Stress fractures related to pregnancy may occur at various other sites, including the spine, coccyx, femoral neck, superior and inferior pubic bones, ischiopubic arch, or pubic body wrist or clavicle (Figures 7 and 8) [9, 11].

**Peripartum pubic separation**

Separation of the pubic symphysis is an uncommon injury that may occur in the antepartum, intrapartum, or postpartum period and cause suprapubic, sacroiliac or thigh pain [3]. The reported incidence of peripartum pubic separation varies from 1 in 300 to 1 in 30,000 deliveries [3, 8, 12]. The nonpregnant gap is 4–5 mm, and it increases 2–3 mm in every pregnancy under the influence of the pregnancy hormones. The hormone relaxin has been identified as a major contributor to these changes in joint laxity during pregnancy [2].

Widening and hypermobility of the sacroiliac joint and the symphysis pubis begins at 10–12 weeks of pregnancy. The widening of the symphysis pubis is visible on radiographs as early as the first trimester, becomes maximum near term [2], and may last approximately 4–12 weeks postpartum [8].

Pubic diastasis usually occurs intrapartum, in association with multiparity, fetal macrosomia, precipitous labor, powerful uterine contractions, cephalopelvic disproportion, forceps delivery, or previous pelvic pathology or trauma and use of McRoberts manoeuvre, but it has also occurred in the antepartum period [3, 8, 13].

Pain or discomfort in the pelvic region, centered on the symphysis pubis joint and aggravated by weight-bearing and abduction, is usually the main symptom associated with restricted leg abduction and waddling gait. Some patients report clicking or popping of the lower back and hip joints in and out as they walk or change position [3].

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**Figure 6:** Stress fracture of the femoral head in the postpartum: axial a) and sagittal b) CT views show a subtle fracture line (arrows).

**Figure 7:** Stress fracture of the coccyx in the immediate postpartum. Sagittal CT view a) and T1 b) and T2 c) MRI views show the fracture line (arrow) associated with adjacent bone and soft tissue edema (courtesy Dr M. Kasbi).
The diagnosis of diastasis is based on the persistence of symptoms and a symphysis pubis separation of 10–13 mm on X-ray, ultrasound, or MRI scan (Figure 9). CT might show gas in the joint space. MRI enables the visualization of high water content of the pubic cartilage and focal edematous changes to the parasymphyseal bones and surrounding soft tissues (Figure 10) [3].

Pubic separation is conservatively managed with bed rest, analgesia, and activity restriction if the diastasis is 25 mm, but extreme cases may require surgery [3]. Additionally, intra-symphysial injection combining hydrocortisone, chymotrypsin, and lidocaine once a day for 3–7 days, depending on the severity of diastasis, has demonstrated rapid relief [8].

Symptoms usually arise the day after delivery, as soon as the patient adopts a sitting position. Abnormalities in the area of the sacroccocygeal joint may be evaluated with static and dynamic lateral radiography in the standing and sitting positions.

Dislocation and severe hypermobility (above 35°) are typically associated with symptoms. Although normal mobility and hypermobility are often encountered, posterior dislocation of the coccyx has been shown to specifically relate to childbirth. In far more rare instances, a true fracture of the coccyx (Figure 7) or fifth sacral vertebra may occur and lead to pseudarthrosis. MRI is recommended as a second-line modality when radiography fails to provide an adequate explanation for the symptoms [1].

Figure 8: Stress fracture of the femoral neck in the postpartum: coronal a) and sagittal b) CT views in bone reconstructions show a fracture line at the inner part of the neck (arrow).

Figure 9: Symphysis pubis separation postpartum: coronal STIR MRI view shows enlargement of the joint space with bone edema of the parasymphyseal pubis bones and adjacent soft tissues.

Sacroccocygeal Dislocation and Coccygodynia
Coccygodynia is defined as pain in the coccyx area occurring in the sitting position. Childbirth is a common cause, estimated to explain 7.3% of chronic coccygodynia in women. Difficult deliveries and a short perineum are the two main risk factors for this condition.

Figure 10: Postpartum symphysis pubis separation: axial T1 a) and STIR b) MRI views show high water content of the pubic cartilage with focal edematous changes to the parasymphyseal pubis bones.
**Inflammatory sacroiliitis**

The incidence of pregnancy-related inflammatory sacroiliitis is about 1 in 10,000 [14]. This condition is due to sacroiliac joint strain during pregnancy and after delivery that stretches and even tears ligaments and the capsule of the SI joints during parturition as well as bleeding or synovial effusion into the joint.

Inflammatory sacroiliitis is usually associated with fever, leukocytosis, and a raised erythrocyte sedimentation rate (ESR). The outcome of this disease is unclear. It usually resolves in a period of a few months, but clinical follow-up must be more intense when the haplotype HLA B27 is present. Increased mechanical stress during pregnancy and delivery may lead to the onset of inflammatory sacroiliitis [15].

MRI shows a focal area of low T1-weighted and high T2-weighted imaging signal, with gadolinium enhancement of the joint space and subchondral bone in the inferior and posterior part on the joint (Figures 11–14). MRI changes of the sacroiliac joint are usually not as prominent as in axial SpA patients, and may even be absent [16].

**Disk herniation and sciatica**

The relationship between pregnancy and disk herniation remains controversial [1]. True sciatica is rare, estimated to occur in 1% of pregnancies and cause cauda equina syndrome in about 1 in 10,000 pregnant women [8]. Clinical presentation of relatively sudden radicular pain or numbness, typically involving both legs, should alert to the possibility of a herniated disc [8].

Imaging is only required in cases of uncontrolled pain, motor deficiency, or presence of other spinal canal stenosis symptoms. MRI without the injection of a contrast medium is the modality of choice, but it has

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**Figure 11:** Bilateral inflammatory arthritis in the postpartum: coronal T1 a), STIR b), and fat-suppressed T1 after gadolinium administration c) Focal area of low T1 and high T2 signal with gadolinium enhancement of the subchondral bone in the inferior and posterior part on the joint (arrow). The same signal modifications are observed in the joint space.

**Figure 12:** Inflammatory arthritis of sacroiliac joints in the postpartum: axial STIR a) and b) and frontal STIR c) MRI images show high signal intensity of the right and left joint space (*), subchondral bone (->), and soft tissue (>) with no fluid collection.

**Figure 13:** Inflammatory arthritis of the right SI joint of the postpartum in a 36-year-old woman with elevated ESR. Axial CT images in bone a) and soft tissue b) Algorithm: subchondral bone erosions and condensation of the inferior part of the right SI joint with no soft tissue swelling. CT-guided biopsy did not show any evidence of infection.
to be correlated with clinical symptoms [1]. Conservative symptomatic therapy, including bed rest, ice, physical therapy, lumbar support, analgesia, and muscle relaxants, are usually sufficient for uncomplicated radicular pain [8].

**Lumbosacral plexopathy**

Lumbosacral plexopathy is a delivery complication resulting from the compression of the lumbosacral trunk by the descending fetal head against the sacral wing. The right side is most frequently involved, probably due to orientation of the fetal head.

Clinical presentation is typical, including acute radiculopathy during delivery, with subsequent foot drop during the postpartum period. Neural lesions usually recover within a few months.

MRI typically shows hypertrophy and high T2-weighted imaging signal intensity of the involved nerve roots.

Recent 3D anatomic nerve-selective MR neurography based on diffusion-weighted sequences with directional encoding may help to emphasize focal impairment of the lumbosacral plexus.

Differential diagnosis includes pyomyositis and hematoma of the piriformis muscle due to prolonged labor [1].

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**Figure 14:** Inflammatory arthritis of the right SI joint of the postpartum in a 27-year-old woman. Axial CT image **a)** subtle ossifications of the extra-synovial part of the SI joint, T1-weighted **b)** and STIR **c)** and **d)** MR images: low T1 and high T2 signal intensity of the right SI joint cavity with high T1 and STIR signal of the subchondral bone.

**Figure 15:** Pyogenic arthritis of the left sacroiliac joint in the postpartum: axial **a)** and coronal **b)** T1 MR images, as well as axial **c)** and coronal **d)** Fat-suppressed T1 MRI images after gadolinium administration show fluid collection in the joint space (arrow), associated with bone and soft tissue edema.
**Pyogenic sacroiliitis**

Infectious sacroiliitis is a rare condition that is usually related to delivery and occurring in the early postpartum period [1]. Pyogenic sacroiliitis is usually unilateral, but it may be bilateral [17].

Increased pelvic movements may induce microtrauma to joint surfaces, thus making pregnant women susceptible to transient bacteremia [18]. Hematogenous contamination of the joint results from a genital tract infection and may coexist with a urinary tract infection or endometritis. Staphylococcus aureus is the most prevalent organism encountered [1].

Radiographs are normal in the early disease; otherwise they may show blurring of the joint margins, widening joint space, or periarticular erosions. CT allows a better assessment of bone abnormalities and remains the method of choice to guide biopsy. MRI has shown to be superior to CT in the diagnosis of inflammatory and infectious sacroiliitis [17]. It demonstrates joint space fluid collection with inflammatory signs in both subchondral bone and neighboring soft tissue (Figure 15).

Findings supporting infectious rather than inflammatory disease include unilateral involvement and marked bone marrow and soft tissue edema [17]. Other reported pelvic infections in the postpartum period include piri-formis muscle abscess resulting from a direct forceps injury and osteomyelitis of the symphysis pubis [1].

**Conclusion**

The combination of biomechanical, hormonal, and vascular changes in pregnancy may result in a wide variety of musculoskeletal disorders. Stress on the axial skeleton, pelvic rim, and genital tract during childbearing and childbirth may lead to acute disorders, including non-specific pain, neurologic compression, joint disruption, and hematogenous infections. The radiologist has to be aware of these conditions to make an accurate diagnosis.

**Competing Interests**

The authors have no competing interests to declare.

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