

Avulsion Injuries of the Pelvis and Hip

Avulsionsverletzungen von Becken und Hüfte

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ZUSAMMENFASSUNG

Hintergrund Avulsionsverletzungen sind typische Verletzungen des adolescenten Sportlers, finden sich jedoch auch beim Erwachsenen. Typische Lokalisationen sind der Ursprung bzw. die Insertion von Sehnen und Bändern, beim Adoleszenten häufig auch die noch nicht vollständig verknöcherten Apophysen. Becken und Hüfte sind aufgrund der zahlreichen hier entspringenden/ansetzenden Muskeln und Sehnen anatomisch prädestiniert für Avulsionsverletzungen. Neben dem Erkennen der typischen Befunde in der Bildgebung sind Anamnese und klinische Untersuchung essenziell für die korrekte Diagnose dieser meist akuten, nicht selten aber auch chronischen Verletzungen.

Methode In diesem Übersichtsartikel werden die typischen Avulsionsverletzungen an Becken und Hüfte beschrieben und anhand von geeignetem Bildmaterial aus dem eigenen Patientenkollektiv illustriert. Es wird dabei für jede Avulsionsverletzung separat auf den Verletzungsmechanismus, die

klinische Untersuchung, den radiologischen Befund und entsprechende Therapiemöglichkeiten eingegangen.

Ergebnisse und Schlussfolgerung Bei Kenntnis der musklotendinösen Anatomie im Bereich des Beckens/der Hüfte sowie der typischen Verletzungsmuster in der Bildgebung ist eine schnelle und korrekte Diagnose von Avulsionsverletzungen häufig bereits durch die klinische Untersuchung und konventionelle Röntgendiagnostik möglich. Weiterführende Diagnostik, insbesondere Ultraschall und MRT, kann bei inkonklusivem Röntgenbefund oder zur Beurteilung der Retraktion der Sehnen bei nichtknöchernen Avulsionen bzw. zur Abschätzung der Weichteilverletzung ergänzend durchgeführt werden. Die Kenntnis potenzieller Komplikationen von akuten/chronischen Verletzungen ist hilfreich, um unnötigen Untersuchungen oder invasiven Eingriffen vorzubeugen. Meist führt eine konservative Therapie von Avulsionsverletzungen zu funktionell guten Ergebnissen, bei Leistungssportlern oder großer Dislokation/Retraktion von Knochenfragmenten oder Sehnenstümpfen kann jedoch eine operative Refixation erwogen werden, um die Rehabilitation zu beschleunigen.

Kernaussagen:

- Avulsionsverletzungen kommen häufig bei Jugendlichen, aber auch im Erwachsenenalter vor.
- Kenntnisse der muskuloskeletalen Anatomie helfen, typische Verletzungsmuster in der Bildgebung zu erkennen.
- Der Traumamechanismus sowie die klinische Untersuchung und Röntgenmorphologie sind häufig ausreichend zur Diagnosestellung.
- Eine weiterführende Schnittbilddiagnostik ist zur Evaluation einer Sehnenretraktion/Fragmentdislokation und Planung der weiteren Therapie hilfreich.
- Die konservative Therapie ist hinsichtlich der Funktion meist erfolgreich. Die operative Therapie kann bei Dislokation oder Retraktion indiziert sein.

ABSTRACT

Background Avulsion injuries of the pelvis and hip region are typical injuries in adolescent athletes but can be found in adults as well. Typical sites for avulsion injuries include the origin/insertion of tendons and ligaments. Among adolescents, the not yet ossified apophysis is also frequently involved. The pelvis and hip are especially prone to such injuries due to their complex musculotendinous anatomy. Clinical history and

physical examination in combination with the recognition of typical imaging findings are essential for correct diagnosis of these mostly acute, but sometimes also chronic injuries.

Methods This review article describes typical avulsion injuries of the pelvis and hip and illustrates common radiological findings. Taking current literature into account, there is a special focus on the trauma mechanism, clinical examination, typical imaging findings and clinical management.

Results and Conclusion Detailed knowledge of musculotendinous anatomy and typical injury mechanisms allows a correct diagnosis of avulsion injuries often only based on clinical examination and radiographic findings. Further imaging with ultrasound and MRI may be necessary to evaluate tendon retraction in non-osseous avulsion injuries and extent of soft-tissue damage. Knowledge of potential complications of acute/chronic injuries can help to avoid unnecessary examinations or invasive interventions. Conservative management of avulsion injuries usually leads to functionally good results. However, in the case of competitive athletes, relatively wide

bone fragment dislocation or marked tendon retraction, operative re-fixation may be considered in order to expedite the rehabilitation process.

Key Points:

- Avulsion injuries are common injuries at the pelvic region especially in adolescent athletes, due to not yet ossified apophysis.
- Excellent anatomical knowledge is essential for proper diagnostic evaluation and predicting the mechanism of injury.
- Imaging plays a crucial role in diagnosing avulsion injuries starting from X-Ray and using MRI and CT for anatomical details by utilizing multiplanar capabilities.

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Introduction

Pelvic avulsion injuries can occur in both adolescents and adults when either the apophysis is not yet completely fused or the enthesis, i. e. the site of attachment of a tendon or ligament, cannot withstand the tractional force encountered. Anatomically, the enthesis refers to the site of insertion of a tendon or ligament and the adjacent tissues which are functionally related [1]. It serves important functions in stress concentration and smooth transfer of force between different tissue media and can be classified as fibrous and fibrocartilaginous as well as direct and indirect types [2, 3]. Avulsion injuries of the enthesis or apophysis can result in a broad range of pathologies from sole tendinous or ligamentous insertional strain at the attachment site to a complete avulsion fracture with a displaced bone fragment or apophysis. The pelvis is involved in many types of avulsion injuries due to its diverse muscular framework and the origin of several muscles crossing two joints of the lower extremity which additionally puts them at risk for such an injury. Pelvic avulsion injuries can present in an acute setting as a result of a single trauma but can also be encountered as chronic and slowly evolving injuries due to repetitive stress on the attachment site. In adults, avulsion injuries are mostly soft tissue avulsions of the entheses, whereas a displaced apophysis and bony fragment may be commonly seen in the adolescent athlete.

Imaging plays a crucial role in diagnosing avulsion injuries of the pelvis. Conventional radiographs are the first-line diagnostic measure in traumatic pelvis injuries that aid in defining osseous separation of apophyses or bone fragments, but can be of limited use due to tissue overlap. Typical trauma history, clinical examination and findings of conventional radiographs are often sufficient for diagnosis with no need for further imaging. Magnetic resonance imaging (MRI) and computed tomography (CT) are excellent modalities for the evaluation of anatomical details by utilizing

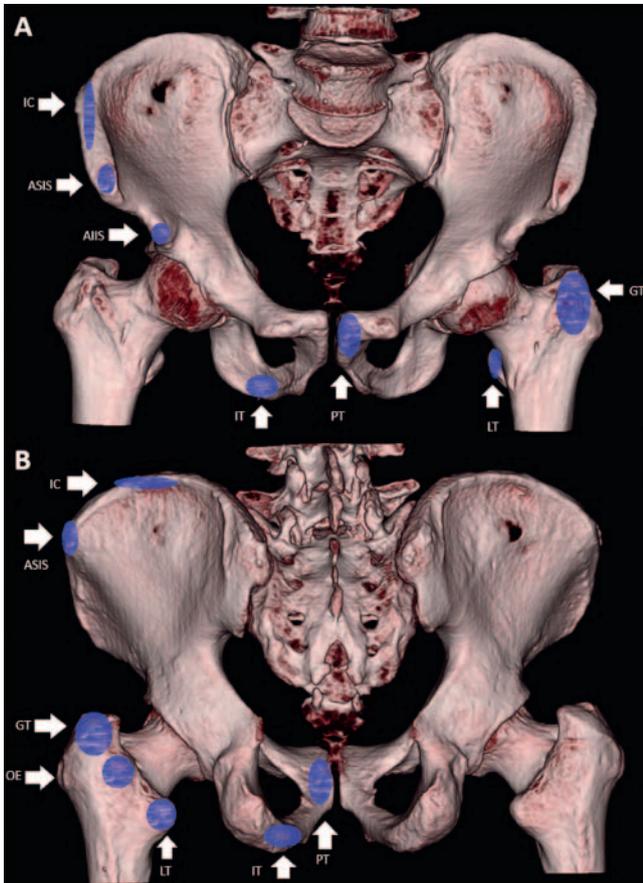
multiplanar capabilities and avoiding tissue overlap. CT is the modality of choice for confirming not only the presence of a displaced ossified apophysis or bone fragment but also shows the extent of callus formation or heterotopic ossification as a result of chronic or old avulsion injuries. In contrast, MRI is best at demonstrating soft tissue changes such as tendon or muscle strain, bone marrow edema, hematoma as well as soft tissue avulsion injuries. It is also best at demonstrating tendon retraction and can aid the clinician in identifying patients that may benefit from operative management. Ultrasound is also an excellent modality for demonstrating avulsion injuries in the acute setting, but markedly relies on the expertise of the sonographer and often lacks the possibility to show the anatomical relation of the injured structure to adjacent bones, tendons, and muscles in a single image.

This review article focuses on the various types and locations of avulsion injuries of the pelvis and hip (► **Fig. 1**). It describes both typical apophyseal avulsion injuries in adolescence as well as avulsion injuries that can occur in adulthood. Eberbach et al. has studied the frequency of pelvic/hip avulsion injuries (► **Table 1**) [5]. Anatomical details, typical history, mechanism of injury, and clinical findings are discussed and radiographic, CT, and MRI characteristics are illustrated.

Pelvic avulsion injuries:

Avulsion of the iliac crest

The iliac crest stretches posteriorly from the anterior superior iliac spine to the posterior superior iliac spine. The iliac crest is the site of attachment for the anterior abdominal wall muscles. Its avulsion results from forceful eccentric contraction of muscles in lateral flexion and rotational movement of the trunk, causing excessive strain of the abdominal muscles [4]. This injury pattern



► **Fig. 1** 3 D reconstruction with typical sites of pelvic avulsion injuries in **A** anterior and **B** posterior view. Abbreviations: AIIS: anterior inferior iliac spine, ASIS: anterior superior iliac spine, GT: greater trochanter, IC: iliac crest, IT: ischial tuberosity, LT: lesser trochanter, OE: obturator externus muscle insertion, PT: pubic tubercle.

► **Abb. 1** 3D-Rekonstruktion mit Darstellung der typischen Lokalisationen für Avulsionsverletzungen des Beckens in der anterioren **A** und posterioren **B** Aufsicht. Abkürzungen: AIIS = Spina iliaca anterior inferior; ASIS = Spina iliaca anterior superior; GT = Trochanter major; IC = Crista iliaca; IT = Tuber ischiadicum; LT = Trochanter minor; OE = Insertion des M. obturator externus; PT = Tuberculum pubicum.

is uncommon and accounts for only about 1–2% of all avulsion injuries of the pelvis/hip region [5]. On physical examination, the patient usually complains about tenderness along the iliac crest [6, 7]. Radiographs can be of limited use, potentially showing asymmetry between both iliac crest apophyses. MRI scan, in contrast, shows insertional edematous changes with osseous separation and avulsion of the abdominal wall muscle origins (► **Fig. 2**). This type of avulsion injury has an excellent outcome with conservative management. However, surgical management may be considered in heavily displaced fragments (more than 30 mm) or if patients require rapid rehabilitation with quick return to sports activities [8, 9].

► **Table 1** Frequency of pelvic/hip avulsion injuries according to Eberbach et al. [10]

AIIS	33.2%
IT	29.7%
ASIS	27.9%
IC	6.7%
LT	1.8%
SCPS	1.2%
Other	< 1%

AIIS: anterior inferior iliac spine, ASIS: anterior superior iliac spine, IC: iliac crest, IT: ischial tuberosity, LT: lesser trochanter, SCPS: superior corner of the pubic symphysis.

Avulsion of the anterior superior iliac spine

The anterior superior iliac spine represents the origin of the sartorius muscle and in parts of the tensor muscle of the fascia lata. Avulsion injury of the anterior superior iliac spine is relatively common and represents about 28% of all pelvic avulsion injuries according to a systematic review by Eberbach et al. (► **Table 1**) [10]. Sprinters or jumpers are typical athletes at risk for this type of injury that occurs during forceful extension and sudden sprain of the hip. On physical examination, palpating the area just below the most anterior aspect of the iliac crest can provoke pain, though the avulsed fragment may be palpated as well [7]. The avulsed fragment is typically displaced distally and laterally and might be falsely mistaken as an avulsion injury of the anterior inferior iliac spine. Clinical history, typical findings on examination and conventional radiographs are usually sufficient for diagnosis (► **Fig. 3**). CT imaging or MRI is only necessary when conventional radiography is inconclusive or in case of delayed presentation of the patient at the clinic. MR imaging improves the detection of subtle injuries and demonstrates the extent of soft tissue damage and retraction of the sartorius muscle tendon [11, 12]. These avulsion injuries can lead to marked hematoma and excessive callus formation that might lead to meralgia paresthetica due to compression of the lateral cutaneous nerve [13, 14]. If the referring clinician or radiologist is unaware of this type of injury, the changes might be mistaken for a bone tumor with soft tissues involvement [15]. Usually rapid healing of this injury can be accomplished with conservative treatment in the case of minimally displaced fractures and this is the most selected treatment option [16, 17]. Surgical management with open reduction and screw fixation may be considered in widely displaced avulsions with a gap of more than 15–20 mm. The initial recovery period may then be shorter with an earlier return to sports, but the outcome in the mid-term may not be significantly different between conservative and operative treatment approaches [10, 18–20].

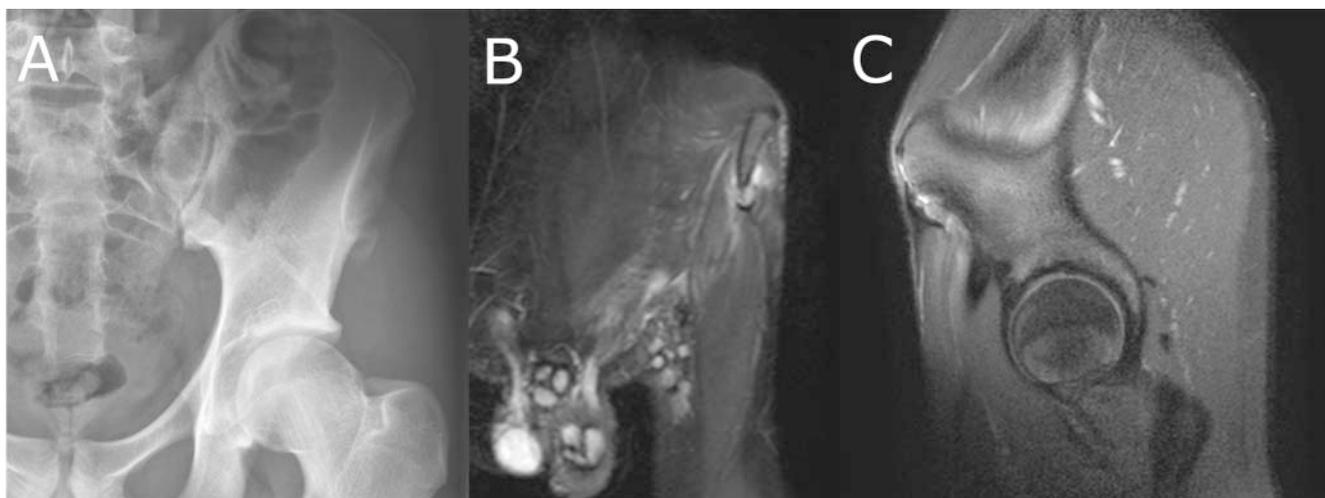
Avulsion of the anterior inferior iliac spine

The anterior inferior iliac spine is the origin of the straight head of the rectus femoris muscle, whereas the reflected head arises from



► **Fig. 2** Axial X-ray of the right hip **A**, coronal T2 STIR **B** as well as axial T2 **C** images of a 17-year-old soccer player: avulsion injury of the iliac crest extending from the anterior superior iliac spine to the posterior superior iliac spine. The avulsion injury cannot be depicted on conventional radiograph. Only MRI shows the non-displaced avulsion of the not yet ossified iliac crest apophysis.

► **Abb. 2** Axiale Röntgenaufnahme der rechten Hüfte **A**, koronares T2-STIR-Bild **B** und axiales T2-Bild eines 17-jährigen Fußballspielers: Avulsionsverletzung der Crista iliaca von der Spina iliaca anterior superior bis zur Spina iliaca posterior superior. Die Avulsionsverletzung ist auf dem Röntgenbild nicht zu sehen, erst die MRT-Untersuchung zeigt die nicht dislozierte Avulsionsverletzung der noch nicht verknöcherten Apophyse der Crista iliaca.

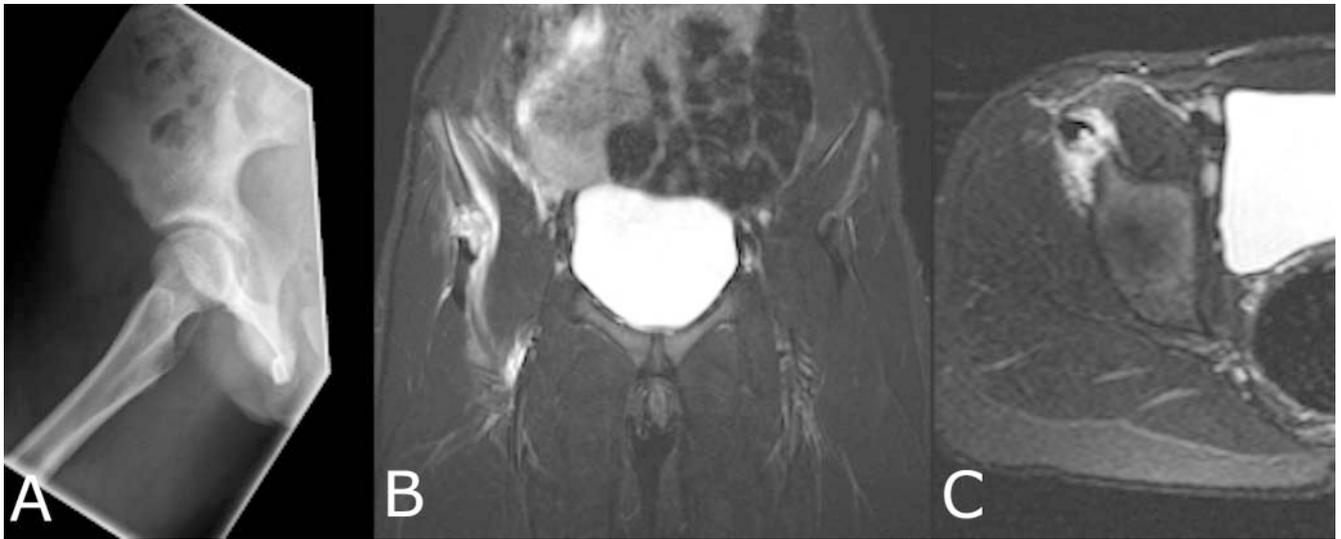


► **Fig. 3** X-ray of the left hip in ap-projection **A**, coronal T2 STIR image **B** and sagittal PD weighted image with fat saturation **C** images of a 15-year-old soccer player: avulsion injury of the anterior superior iliac spine with mildly displaced bone fragment.

► **Abb. 3** Röntgenbild der linken Hüfte in ap-Projektion **A**, koronares T2-STIR-Bild **B** und sagittales PD-gewichtetes Bild mit Fettsättigung **C** eines 15-jährigen Fußballspielers: Avulsionsverletzung der Spina iliaca anterior superior mit gering disloziertem Knochenfragment.

a groove above the rim of the acetabulum. The rectus femoris muscle crosses two joints and is therefore prone to injury similar to the sartorius muscle arising from the anterior superior iliac spine. The rectus femoris muscle flexes the hip joint and extends the leg at the knee joint. Thus, avulsion injuries of the anterior inferior iliac spine or a strain of this particular muscle is a consequence of a forceful extension at the hip. Typical injury patterns occur during sprinting, jumping, or kicking and are common in sports like soccer. This avulsion injury is about as common as that of the anterior superior iliac spine and accounts for about

20–25% of all pelvic avulsion injuries [21]. On clinical examination there is anterior hip/groin pain and tenderness on palpation directly overlying the superior aspect of the hip joint. Patients experience pain with active hip flexion against resistance or during hip flexion combined with knee extension. On conventional anterior-posterior radiographs of the pelvis, a small cortical avulsion or displaced bone fragment may be seen. However, oblique views of the pelvis sometimes aid in confirming the diagnosis. Further imaging with ultrasound or MRI may be required if conventional radiographs are inconclusive. Especially MRI can



► **Fig. 4** Axial X-ray of the right hip **A**, coronal **B** and axial **C** T2-STIR image of a 13-year-old female athlete: avulsion injury of the anterior inferior iliac spine with only minimal tendon retraction.

► **Abb. 4** Axiales Röntgenbild der rechten Hüfte **A**, koronares **B** und axiales **C** T2-STIR-Bild einer 13-jährigen Athletin: Avulsionsverletzung der Spina iliaca anterior inferior mit nur minimaler Retraktion der Sehne.

show the extent of accompanying soft tissue injury and muscle retraction (► **Fig. 4**). Of note is a potential extensive heterotopic callus formation at the superior aspect of the acetabulum that may cause femoro-acetabular impingement due to a narrowing of the space between the greater trochanter and the acetabular roof. This femoro-acetabular impingement may be the cause of chronic hip pain in youth [22]. Avulsions of both the anterior superior and anterior inferior iliac spine tend to be less symptomatic and disabling than avulsions of the ischial tuberosity with a relatively shorter recovery time [23].

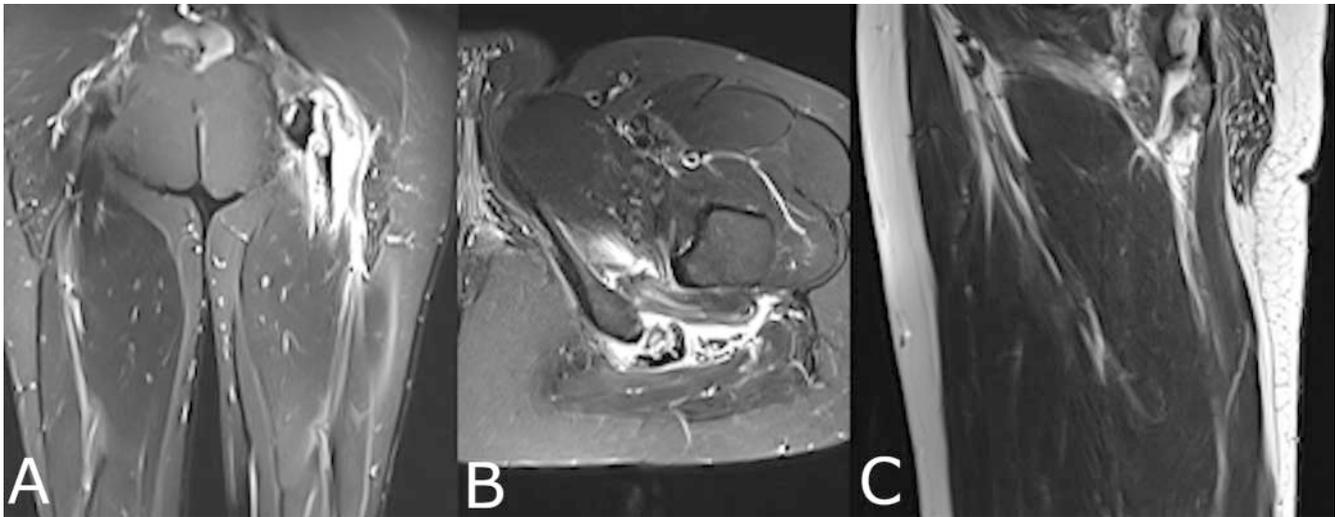
Avulsion of the ischial tuberosity

According to a study by Rossi et al., the ischial tuberosity is a common site for pelvic avulsions especially in adolescents [5]. The ischial tuberosity represents the site of insertion of the hamstring muscle group, namely the long head of the biceps femoris, the semitendinosus and the semimembranosus muscle. Athletes in competitive sports, such as soccer players, runners and dancers, suffer from this injury upon forceful active contraction of the hamstrings during powerful flexion of the hip joint with the knee in extension or sudden and excessive passive lengthening [24]. Patients present classically with sudden pain in the buttock region and proximal dorsal thigh which is sometimes associated with the inability to walk. Typically the pain is more pronounced during sitting compared to standing upright. Although the history and trauma mechanism in conjunction with clinical signs, such as localized swelling, pain, and limitation of motion, are somewhat characteristic, this avulsion injury is often misinterpreted and diagnosis is delayed. Acutely, a non-displaced avulsion of the ischial tuberosity appears as a curved, sharply marginated piece of bone adjacent to its origin (ischial epiphysiolysis) as seen in ► **Fig. 5**. One should be aware of a potential misdiagnosis as a neoplastic

bone formation [25]. Usually conventional radiographs are sufficient for correct diagnosis of an ischial tuberosity avulsion fracture and can demonstrate displacement of the bony fragment. However, ultrasound and MRI may be useful as an additional modality showing the extent of soft tissue injury including non-osseous avulsions and the formation of circumscribed hematoseroma. To date there is no clear guideline on the management of avulsion injuries of the ischial tuberosity but most centers favor conservative treatment. Operative treatment with open reduction and internal fixation is considered only if the avulsed fragment is widely displaced. A publication by Singer et al. suggests a displacement of more than 15 mm as an indication for operative management [10, 26]. As a complication of an avulsed ischial tuberosity, sciatica may occur, which is related to irritation of the sciatic nerve by the avulsed bony fragment and/or hypertrophic bony callus formation or heterotopic ossification [27] as can be seen in ► **Fig. 6**. Another complication of a pronounced bone formation at the site of the ischial tuberosity following an avulsion injury and consecutive narrowing of the ischiofemoral space may be the development of an ischiofemoral impingement syndrome [28]. This syndrome refers to the impingement of soft tissues, primarily the quadratus femoris muscle, between the ischial tuberosity and lesser trochanter of the femur.

Avulsion injuries at the pubic ramus and symphysis pubis

The long and short adductor muscles of the hip arise from the pubic body and symphysis as well as the inferior pubic ramus, namely the adductor longus, adductor brevis, and gracilis muscles, as well as the distal rectus abdominis muscle [29]. In the acute setting the adductor longus muscle is the most often injured muscle, followed by the adductor brevis and the pectineus



► **Fig. 5** Coronal **A** and axial **B** T2-weighted images with fat saturation as well as sagittal T2-weighted image **C** of a 47-year-old female recreational athlete: Avulsion injury of the hamstring muscles at the ischial tuberosity with mild tendon retraction and adjacent fluid collection.

► **Abb. 5** Koronares **A** und axiales **B** T2-gewichtetes Bild mit Fettsättigung und sagittales T2-gewichtetes Bild **C** einer 47-jährigen Hobby-Sportlerin: Avulsionsverletzung der ischiocruralen Muskulatur am Tuber ischiadicum mit geringer Retraktion der Sehnenstümpfe und angrenzender Flüssigkeitskolektion.



► **Fig. 6** X-ray of the pelvis in ap-projection **A** of a 27-year-old male athlete: infero-laterally displaced bone fragment of the ischial tuberosity and inferior pubic ramus on the right side due to an old osseous avulsion injury.

► **Abb. 6** Röntgenbild des Beckens in ap-Projektion **A** eines 27 Jahre alten männlichen Athleten: infero-lateral disloziertes Knochenfragment nach einer knöchernen Avulsionsverletzung des Tuber ischiadicum und des Ramus inferior ossis pubis auf der rechten Seite.

muscle according to a recent study by Serner et al. The gracilis and adductor magnus muscles are rarely involved [30]. Avulsion injury of the adductor muscles is often due to chronic overuse and repetitive microtrauma, and rarely due to sudden forceful contraction against resistance. It typically occurs in soccer, ice hockey, and tennis players [5]. The resultant unilateral pain is localized to the groin and can be relatively nonspecific and its chronic status is often referred to as “athletic pubalgia”. Differential diagnoses include osteitis pubis, sportsman’s hernia, acetabular labral tears

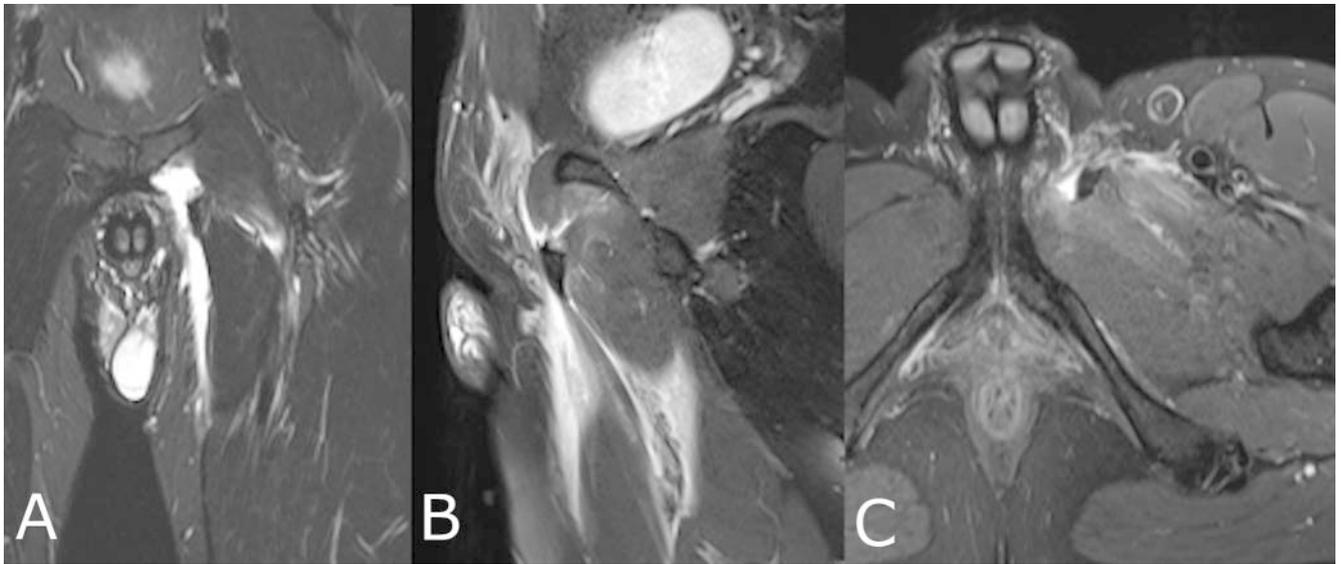
and even lumbar spine disease [31, 32]. Radiography and physical examination can poorly identify the involved muscle since this type of avulsion injury rarely demonstrates a displaced bone fragment but often represents an isolated soft tissue injury. Thus, MRI can aid in the identification of the specific adductor muscle involved and distinguish between a low-grade muscle strain at the site of origin and a full-thickness avulsion with muscle retraction. Treatment is usually conservative, comprising the ceasing of sports activities and decreased weight bearing for a few weeks until a gradual increase of strain is tolerated.

Avulsion of the adductor longus muscle

The adductor longus muscle arises from the front of the pubic body just below the pubic crest with a short, flat and narrow tendon. In its proximal course it is a superficial muscle at the medial aspect of the thigh, anterior to the adductor magnus and brevis muscle. The adductor longus muscle inserts into the middle third of the linea aspera of the femoral shaft between the vastus medialis and adductor magnus muscle with which it is usually blended. It is the most frequently injured adductor muscle and MRI findings (► **Fig. 7**) can vary from low-grade muscle sprain at the origin to complete avulsion with muscle retraction [33, 34].

Avulsion of the gracilis muscle

The gracilis muscle originates from the ischiopubic ramus just medial to the adductor brevis origin. The gracilis muscle lies medial to the adductor longus, brevis et magnus muscles. Avulsion of the gracilis muscle is usually due to chronic overuse, resulting in fatigue fracture rather than an acute avulsion, although a discrete displaced bone fragment may be identified in acute osseous avulsions. Sole avulsion injury of the gracilis is very rare. It is usually



► **Fig. 7** Coronal T2-weighted image with fat saturation **A**, sagittal **B** and axial **C** PD weighted image with fat saturation of a 27-year-old male tennis player: avulsion injury of the adductor longus muscle with mild tendon retraction and adjacent fluid collection.

► **Abb. 7** Koronares T2-gewichtetes Bild mit Fettsättigung **A**, sagittales **B** und axiales **C** PD-gewichtetes Bild mit Fettsättigung eines 27-jährigen Tennisspielers: Avulsionsverletzung des M. adductor longus mit geringer Retraktion der Sehnenstümpfe und angrenzender Flüssigkeitskolektion.

accompanied by extensive avulsion injuries of the nearby adductor longus and brevis muscles [30].

Avulsion of the obturator externus muscle

The obturator externus originates from the external bony margin of the obturator foramen as well as the obturator membrane and passes like a sling under the femoral neck to insert on the piriformis fossa at the medial aspect of the greater trochanter of the femur. The exact mechanism of injury of this muscle is unknown and muscle strain rather than avulsion is mostly reported in the literature. Obturator externus muscle injuries are uncommon and are usually present in extensive injuries of other adductor muscles. However, isolated injuries to the obturator externus muscle occasionally occur [30]. High level athletes such as professional soccer players may be at risk with complaints of anterior hip pain and pain during internal/external rotation of the flexed hip [35]. Isolated muscle strains/low-grade tears of the obturator externus muscle have a benign prognosis with a relatively quick return to play for the athlete.

Avulsion injuries of the proximal femur

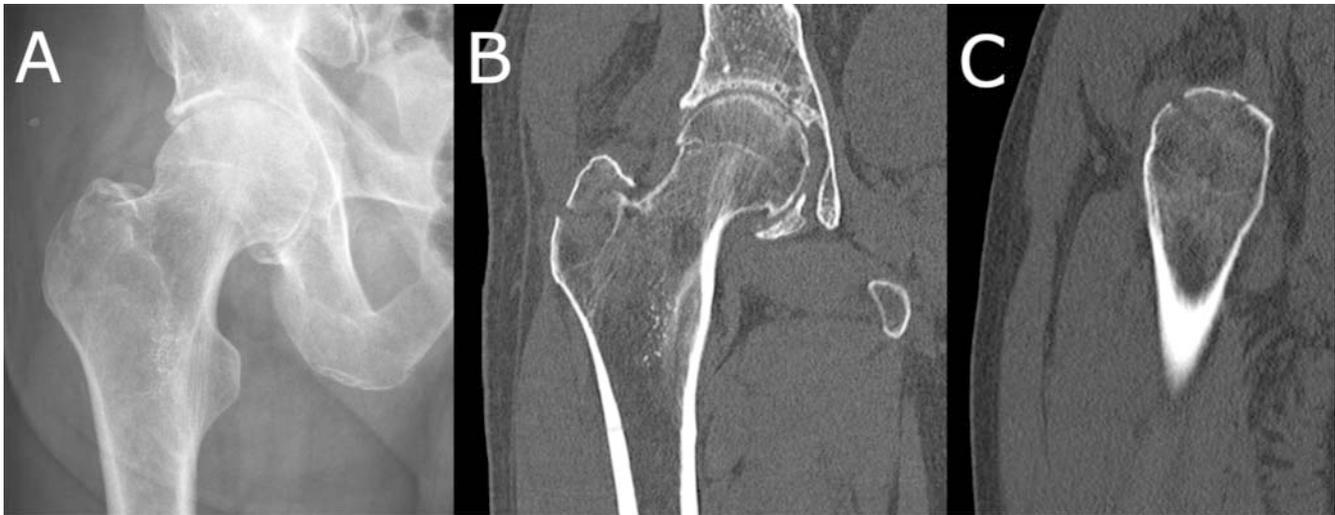
Avulsion of the greater trochanter

Avulsion fracture of the greater trochanter is a rare entity even among apophyseal avulsions of the pelvis in adolescents. A few muscles attach to the greater trochanter which are hip rotators and abductors including the middle and least gluteal, internal obturator, gemelli, and piriform muscles. Avulsion injury of the greater trochanter occurs after a sudden forceful change of direction. Conventional radiographs can show displacement of the

greater trochanter from its origin, although a discrete widening of the non-ossified epiphyseal plate with edematous changes on MRI is more common. A combination of conventional radiographs, clinical symptoms, pain on palpation over the trochanteric region and painful abduction/adduction against resistance often leads to the correct diagnosis. Because of its rare occurrence, there is no clear evidence regarding the treatment of such traumatic avulsions. A conservative approach with restricted range of motion and refraining from sports for about 6 weeks with a subsequent slow increase of stress may be a treatment of choice especially in adolescents [21]. Open reduction and internal fixation might be necessary in the case of wide displacement of the greater trochanter, especially in traumatic fractures of the greater trochanter region due to a direct impact after a fall in the elderly population (► **Fig. 8**). Of note are sporadic reports of subsequent osteonecrosis of the femoral head after avulsion fracture of the greater trochanter that may be the result of concomitant traumatic damage to the circumflex medial artery and its cervical branches [36–38].

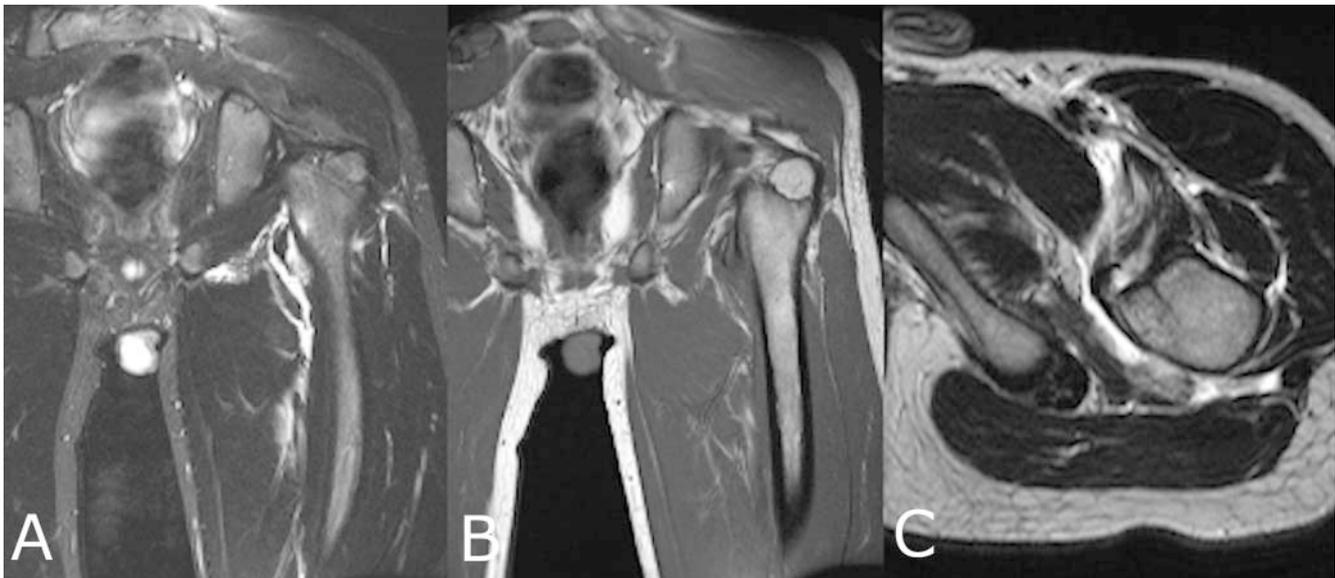
Avulsion of the lesser trochanter

Avulsion fracture of the lesser trochanter is a rare injury pattern encountered in young athletes [39]. It occurs only in about 1–3% of all avulsion injuries of the hip region (► **Table 1**) [10, 21]. The lesser trochanter is the site of insertion of the iliopsoas muscles. Thus, a forceful and abrupt contraction of the iliopsoas muscle may result in avulsion fracture especially in competitive track and field athletes or soccer players but it might also occur following tonic-clonic seizures [40]. It can result in considerable pain and limitation of function usually with hip flexion as a relieving posture. The medial thigh is tender on palpation and active flexion



► **Fig. 8** X-ray of the right hip in ap projection **A**, coronal **B** and sagittal **C** reformats of subsequent CT imaging: Avulsion fracture of the greater trochanter with only mild displacement.

► **Abb. 8** Röntgenbild der rechten Hüfte in ap-Projektion **A**, koronare **B** und sagittale **C** Rekonstruktion der angefertigten CT-Untersuchung. Avulsionsfraktur des Trochanter major mit geringer Dislokation.



► **Fig. 9** Coronal T2-weighted image with fat saturation **A**, coronal T1-weighted **B** and axial T2-weighted image **C** of a 14-year-old adolescent athlete: avulsion injury of the iliopsoas muscle at its insertion at the lesser trochanter without displacement of the not yet ossified apophysis.

► **Abb. 9** Koronares T2-gewichtetes Bild mit Fettsättigung **A**, koronares T1-gewichtetes **B** und axiales T2-gewichtetes Bild **C** eines 14-jährigen jugendlichen Athleten: Avulsionsverletzung der Sehne des M. iliopsoas an der Insertion am Trochanter minor ohne wesentliche Dislokation der noch nicht verknöcherten Apophyse.

against resistance is not possible. Affected patients often respond well to conservative therapy and operative management is seldom necessary [41, 42]. Conventional radiographs demonstrate the displaced lesser trochanter, further evaluation by CT or MRI is usually not necessary (► **Fig. 9**). Caution must be taken when lesser trochanter avulsion is seen in adults, as it can represent a pathologic avulsion fracture due to metastatic involvement [43].

MRI protocol recommendations

In case of suspected avulsion injury of the pelvis or hip region, it is often helpful to start with an axial or cor PD/T2-weighted sequence with fat saturation with a large FoV (max 40 cm, at least 256 × 256 matrix, 5–6 mm slice thickness) including the entire pelvis as a bilateral survey. If the site of injury can easily be identified, the following sequences should be acquired with a small FoV

(max. 16–24 cm) with imaging of only one side of the pelvis or both hamstring/adductor origins. At least one sequence should be T1-weighted without fat saturation. Coronal T1 may be the best choice. Additional PD or intermediate weighted sequences in ax, sag and cor orientation adapted to the site of injury should be performed. T2-weighted sequences without fat saturation may be of additional benefit. These unilateral sequences should allow for detailed visualization of the anatomy. Therefore, a small field of view with a high in-plane resolution (at least 1.0 mm × 1.0 mm in-plane) as well as through plane resolution (max. 3.5 mm slice thickness) should be used. Detailed recommendations are published by the European Society of Skeletal Radiology (ESSR) and “AG Bildgebende Verfahren des Bewegungsapparates der Deutschen Röntgengesellschaft”.

Summary

Pelvic avulsion injuries are common, especially in young athletes, but can also occur in adults. Typical history of trauma, clinical examination and conventional radiographs often lead to the diagnosis. If findings are inconclusive, further imaging, such as CT or MRI, can aid in diagnosis and decision making regarding conservative vs. operative management. Most avulsion injuries can be adequately treated by conservative management, but widely displaced bone fragments/apophyses or significant tendon retraction in a competitively active athlete may favor operative management due to faster recovery and shorter return to play. Chronic or old avulsion injuries can result in extensive heterotopic bone formation that may cause impingement syndromes around the hip joints. Recognition of characteristic radiographic patterns and familiarity with musculoskeletal pelvic anatomy will aid in accurate diagnosis of pelvic avulsion injuries and support clinical management. In addition, awareness of typical imaging findings prevents unnecessary examinations and even invasive biopsies since chronic injuries may resemble aggressive neoplastic or infectious processes.

Conflict of Interest

The authors declare that they have no conflict of interest.

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