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11.1 Introduction

Avulsion fractures of the pelvis are common injuries among sporting youngsters. A powerful, sudden, eccentric muscle contraction is the primary cause of these indirect injuries [1]. Most of them occur between the puberty and the middle of the third decade [2]. Their incidence is estimated to be increasing as the participation of adolescents in competitive sports is becoming more and more extensive.

In the adulthood, the muscle–tendon–bone complex usually fails at the muscle–tendon junction; on the contrary, before skeletal maturity, the weak junction is within the bony attachment. The physeal plate interposed between the tendon insertion (ossification center) and the rest of the bone is prone to distraction injuries when the applied force overcomes the ultimate tensile strength of the cartilage [3]. Some of these lesions, occurring in the late adolescence, seem to involve completely fused apophyses: in those cases, the radiologic fusion

is supposed to conceal a persistently weak connection.

The most commonly involved anatomical sites are the ischial tuberosity (IT) and the anterior inferior iliac spine (AIIS), followed by the anterior superior iliac spine (ASIS), the superior corner of the pubic symphysis (SCPS), the iliac crest (IC), the lesser trochanter (LT), and the greater trochanter (GT) [2, 4].

11.2 Clinical Presentation and Imaging

The patients who sustain an acute avulsion injury of the pelvis complain about a sudden, acute pain arisen from a forceful muscular contraction. Usually, the subject falls and keeps the limb and/or the trunk in an antalgic position suitable to relax the corresponding muscle.

Soft tissues above the apophysis are tender, usually swollen, sometimes ecchymosed. If the anamnestic data (young age, sport, indirect mechanism) are crossed with an elementary physical examination that reveals significant pain whenever the involved muscle–tendon unit is voluntarily contracted or passively stretched, the diagnosis is easily suspected.

The standard anteroposterior view of the pelvis is sometimes sufficient to confirm the diagnosis. Oblique views of the pelvis and/or an axial view of the hip are often added. The hip anteroposterior view is inappropriate, given the scarcely predictable radiologic appearance of

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ossification centers. The comparison between the affected side and the contralateral healthy side is fundamental not to misdiagnose a simply unfused apophysis as an injury or vice versa [5].

In doubtful situations, the CT scan may solve the diagnostic dilemma, although the relatively higher radiation dose discourages from routine use. The magnetic resonance imaging (MRI) is an accurate, but also expensive technique we should save for very young patients, where the apophyses are still unossified [6]. Ultrasound scan might be as effective as MRI in experienced hands, without the risk of relevant motion artifacts in noncompliant children [7]. Lastly, if the traumatic history is not clear, late presentations of pelvic avulsions may be misdiagnosed as bone tumors: An adequate MRI may allow an accurate differential diagnosis [8].

11.3 Site-Specific Features

11.3.1 Ischial Tuberosity

A powerful contraction of the hamstrings is responsible for IT detachment. Soccer, sprinting, fencing, tennis, and gymnastics are the most commonly involved sports. Pain is located posteriorly, in the buttock. The hip is kept extended and the knee flexed, to relax the hamstrings. Due to the proximity to the ischiadic nerve, a few cases of secondary nerve irritation were described [9–11].

11.3.2 Anterior Inferior Iliac Spine

The direct tendon of the rectus femoris originates from the AIIS and may determine its avulsion (Fig. 11.1). A violent kick, either hitting the ball or missing it, is the commonest mechanism of injury among young soccer players. Tennis players, track and field athletes, and gymnasts may develop the same injury, although rarely, with explosive flexions of the

hip associated with knee extension. The pain is located in the groin, and the hip and knee are flexed to relieve the tension.

When the AIIS heals back in an elongated fashion, it may determine a peculiar type of extra-articular femoroacetabular impingement, limiting flexion and abduction [12]. An arthroscopic spinoplasty was proposed to treat this rare complication.

11.3.3 Anterior Superior Iliac Spine

Sartorius and tensor fasciae latae insert onto the ASIS. Since both these muscles take part in hip flexion, together with abduction and external rotation, their proximal avulsion strikes the same sports listed above for AIIS lesions. The pain, more lateral in the groin, has a similar presentation.

11.3.4 Superior Corner of the Pubic Symphysis

The SCPS is the insertion of the rectus abdominis. A violent contraction, as it might occur in soccer, gymnastics, or fencing, may determine this rare injury. The pain is located over the pubis, and the patient avoids deep breathing, coughing, and laughing.

11.3.5 Iliac Crest

The same sports responsible for SCPS avulsions are involved in IC avulsions (Fig. 11.2). In this case, the oblique abdominal muscles may detach the IC as a consequence of a sudden twist of the trunk. A similar injury may be determined by blunt trauma to the pelvis in various kinds of accident (car accidents, knocking down, etc.). The tenderness located over the IC is associated with the same antalgic behavior described above.

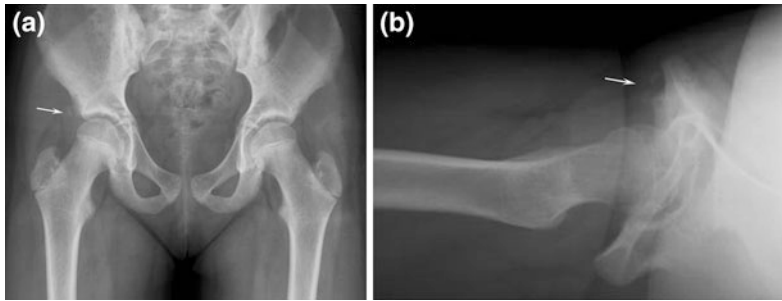


Fig. 11.1 Right AIIS type II avulsion fracture (*arrow*) in a 14-year-old female soccer player. **a** Anteroposterior view of the pelvis. **b** Axial view of the hip

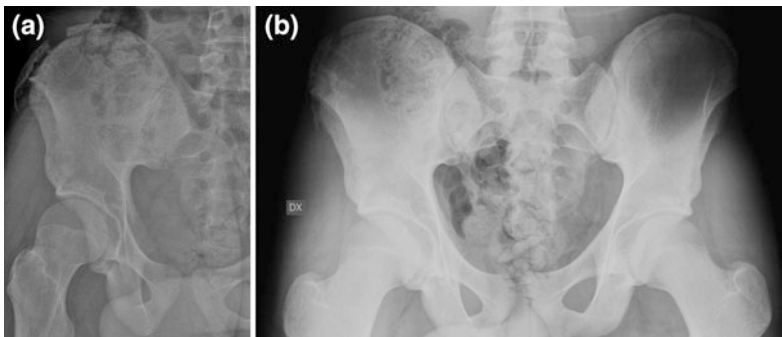


Fig. 11.2 Right type III combined avulsion fracture of IC and ASIS in a 17-year-old high-end male soccer player. Given the large size of the fragment and the patient's high level of activity, a surgical repair was offered. **a** Iliac view of the right pelvic bone at the time of

injury. **b** Anteroposterior view of the pelvis 1 month after open reduction and internal fixation with multiple resorbable screws. The anatomy of the iliac wing is perfectly restored, when compared with the contralateral unaffected side

11.3.6 Lesser Trochanter

The LT is the distal insertion site of the iliopsoas tendon that flexes and rotates laterally the hip. This uncommon avulsion (Fig. 11.3) affects mostly track and field athletes and gymnasts, and the pain is radiated along the medial side of the proximal thigh. Hip extension and internal rotation are painful and consequently avoided.

11.3.7 Greater Trochanter

Glutei medius and minimus insert onto the GT. An abrupt abduction against resistance may determine GT avulsion. Being an extremely rare lesion, it is not possible to determine a sport-specific epidemiology [13, 14].



Fig. 11.3 Right type II LT avulsion fracture (*arrow*) in a 14-year-old male gymnast

Differently from most pelvic avulsions that have excellent prognosis, the rare GT avulsion was seldom associated with a severe complication, the femoral head osteonecrosis, regardless of the treatment—surgical or conservative [15].

11.4 Classification

The displacement is the most relevant prognostic factor, since large dislocations may determine nonunion, exostosis development, and/or significant loss of muscular strength. McKinney and coworkers have presented a useful classification system based on apophysis displacement [16]. The first three types include acute injuries and the fourth chronic outcomes.

Type I: Undisplaced avulsions

Type II: Avulsions displaced up to 2 cm

Type III: Avulsions displaced more than 2 cm

Type IV: Symptomatic nonunions and painful exostoses

weight bearing. Cryotherapy and NSAIDs are used to relieve the symptoms.

Stage II. In the second decade, the patient, still on crutches, is assisted in gentle active and passive exercises. The pain should be slowly subsiding.

Stage III. In the third decade after injury, the pain should be minimal, active and passive range-of-motion (ROM) exercises are encouraged, and crutches are progressively dismissed.

Stage IV. In the second month after injury, the lesion is healing with significant callus. The patient is allowed to begin a very light athletic training.

Stage V. If no complications occurred so far, the athlete may restore his standard training 2 months after injury.

11.5 Conservative Treatment

Most avulsion fractures of the pelvis may be effectively managed according to the nonoperative protocol set up by Metzmaker and Pappas in 1985 [4]. This protocol includes 5 stages:

Stage I. In the first 7–10 days after trauma, the pain is severe and the patient is either resting or walking with crutches and very restricted

11.6 Surgical Treatment

Only a few cases are eligible for surgery at the time of the first observation (Table 11.1), while it might be a viable option whenever the conservative approach fails [16]. All the painful outcomes may require surgical treatment (type IV), while severely displaced acute injuries (type III) may be considered suitable if the consequent shortening of the attached muscle or

Table 11.1 Site- and type-specific indications

	Type I	Type II	Type III	Type IV
IT	C	C*	C*	S
AIIS	C	C	S/C	S
ASIS	C	C	C	S
SCPS	C	C	C	S
IC	C	C	C	S
LT	C	C	C	S
GT	C	C	S	S

C conservative, S surgical

*S in case of sciatic nerve damage

the prominent profile of the detached apophysis could lead to a significant functional impairment. For instance, a post-traumatic elevated GT may result in abductor mechanism dysfunction with Trendelenburg gait and extra-articular impingement with limitation of abduction. Thus, open reduction and internal fixation of type III GT avulsions are often advocated [17]. The recent recognition of the subspine impingement after AHS displaced avulsion fracture might suggest prompt reduction and fixation of type III AHS injuries in youngsters participating in competitive sports requiring full hip ROM. Lastly, all the patients showing a sciatic nerve damage secondary to a displaced IT avulsion (types II or III) are candidate for timely fixation and nerve revision. As for the technique of fixation, most reports agree about using one or two half-threaded screws with or without washer, the diameter being adjusted according to the fragment size (from 4 to 6.5 mm).

Even though open reduction and screw fixation provide superior anatomical restoration in displaced injuries, and this may improve the post-injury level of performance, there is no consensus about the possibility that surgical treatment allows faster return to sport.

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