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Partial Injury of the Triradiate Cartilage Following Low-energy Trauma

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Case Report

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Abstract

Acute traumatic injuries of the triradiate cartilage are very rare in children and usually result from high-energy trauma associated with other pelvic injuries. Only two sports-related cases of complete injuries of the triradiate cartilage have been reported to date. We herein describe the first case of a partial injury of the triradiate cartilage in a 14-year-old athlete. The patient presented with sudden-onset hip pain and moderate functional impairment. The fracture was confined to the ilioischial synchondrosis, while the remaining triradiate cartilage and the contralateral side were fused. MRI suggested the diagnosis, which was confirmed by CT. This case highlights the importance of carefully evaluating the triradiate cartilage on imaging in young athletes with sudden-onset hip pain, even when the triradiate cartilage remains partially open unilaterally.

Introduction

Pelvic fractures are less common in children than in adults due to the greater elasticity of the pediatric skeleton, which is related to bone pliability, the presence of growth cartilage, and increased ligamentous laxity [1]. The pelvic ring can therefore deform to a greater extent without necessarily fracturing.

Pediatric pelvic fractures can be broadly divided into two groups. The first group includes acute traumatic injuries caused by high-energy trauma such as road traffic accidents : *traumatic hip dislocations*, *acetabular fractures*, and *pelvic ring fractures*. These injuries are rare and may be associated with vascular, visceral, and/or neurological lesions, with variable prognosis. The second group includes *apophyseal avulsion fractures* occurring during sports activities, most commonly involving the anterior superior and inferior iliac spines and ischial tuberosity. These injuries are frequent, usually isolated, and generally have a good prognosis.

In the first group (high-energy trauma), acetabular fractures account for less than 15% of pediatric pelvic fractures [1] and among these acetabular fractures, fewer than 30 cases of triradiate cartilage injuries have been reported in the English-language literature [2]. In the second group (low-energy trauma), only two complete injuries of the triradiate cartilage have been reported so far [3, 4]. Both of them were managed conservatively, with favorable clinical outcome. We report the first case of an isolated partial injury of the triradiate cartilage in an adolescent athlete.

Case Report

A 14-year-old boy sustained a right hip injury while playing handball. While attempting a jump pass, he landed on his right side and experienced sudden-onset right hip pain, forcing him to discontinue the game. Despite the pain, he remained able to bear weight. He consulted his general practitioner a few days later, and a muscle strain was initially suspected. Pelvic MRI was performed 10 days after the injury (Fig. 1). CT was subsequently obtained on the same day to further characterize a suspected right acetabular fracture detected on MRI (Fig. 2). The patient was managed with non-weight-bearing crutches and referred to the orthopedic department for further management. His past medical history was

notable for curettage and bone grafting of a left fibular aneurysmal bone cyst three years earlier, with an uneventful recovery. At clinical examination one month after injury, the range of motion of the right hip was preserved. Pain was elicited only during internal rotation. A pelvic radiograph demonstrated widening of the right triradiate cartilage (Fig. 3). The orthopedic surgeon elected to continue conservative management and requested a follow-up MRI one month later. Follow-up MRI demonstrated persistent bone marrow edema on both sides of a still-widened triradiate cartilage. The right hip joint effusion and adjacent soft-tissue edema had resolved (Fig. 4). At that time, the patient was completely asymptomatic. A gradual return to sport was allowed, provided that no pain occurred. No routine long-term follow-up was considered necessary.

Discussion

During fetal development, three primary ossification centers develop to form the ilium at 11–13 weeks of gestation, the ischium at 16–18 weeks, and the pubis at 22–24 weeks. The triradiate cartilage lies at the junction of these three pelvic bones. In children, it has a Y-shaped configuration : the anterosuperior and posterosuperior limbs correspond to the iliopubic and ilioischial synchondroses, respectively, whereas the vertical limb corresponds to the ischiopubic synchondrosis [2].

The triradiate cartilage is an epiphyseal equivalent composed of hyaline cartilage rich in chondrocytes and extracellular matrix. The adjacent bony margins represent metaphyseal equivalents. At approximately 10 years of age, one or more secondary ossification centers develop within the triradiate cartilage and progressively replace the growth cartilage [5]. Complete closure occurs slightly later in boys than in girls, at approximately 15 and 14 years of age, respectively [5].

The triradiate cartilage plays a key role in the growth of the acetabulum in both height and width. The ilioischial synchondrosis is thought to contribute most to this development [4]. Injury to the triradiate cartilage, particularly when the germinal layer is involved, may result in premature physeal closure leading to acetabular dysplasia due to growth arrest and, subsequently, lateral subluxation of the femoral head [2, 4]. The mechanisms responsible for acute injuries of the triradiate cartilage remain poorly understood, involving compression forces, shear forces, or a combination of both. In the present case, shear forces generated during the jump pass and/or lateral compression sustained during the fall may have contributed to the injury. However, the most likely predisposing factor was the asymmetric closure of the triradiate cartilage. A similar mechanism has been described in juvenile Tillaux fractures, in which persistent physeal cartilage at the anterolateral aspect of the distal tibial physis represents a weakness point. Fortunately, acute traumatic injuries of the triradiate cartilage remain exceptional but are often difficult to diagnose, with nearly half of cases reportedly missed at the initial assessment [2].

The anteroposterior pelvic radiograph is usually the first-line imaging modality for evaluating the triradiate cartilage [6]. However, it demonstrates only the two superior limbs of the cartilage—the iliopubic and ilioischial synchondroses—and does not adequately visualize the vertical ischiopubic synchondrosis [4]. Additional radiographic projections, including inlet and outlet, internal and external

oblique views, have been described to improve the assessment of acetabular fractures and triradiate cartilage injuries [6]. Nevertheless, CT with multiplanar and three-dimensional reconstructions provides comparable, if not superior, diagnostic performance.

In the absence of displacement or an associated osseous fracture, isolated widening of the triradiate cartilage may be difficult to detect on both radiographs and CT, particularly because triradiate cartilage closure is not always bilateral or symmetrical, as illustrated in the present case. MRI is the only imaging modality capable of demonstrating bone marrow edema adjacent to the injured cartilage. This finding should be interpreted with caution, as hematopoietic red marrow within adjacent metaphyseal equivalents may show a physiological high-signal on T2-weighted images. In the setting of acute trauma, the severity of clinical symptoms, adjacent soft-tissue edema, a possible intrapelvic hematoma, and reactive hip joint effusion are additional findings supporting the diagnosis.

Bucholz et al. [7] classified acute traumatic injuries of the triradiate cartilage into three types, based on the Salter–Harris classification. Type I consists of a physeal separation with variable displacement and no associated osseous fragment, resulting in widening of the triradiate cartilage. Type II consists of a physeal separation associated with a metaphyseal fragment. Type V corresponds to a nondisplaced compression injury, in which the triradiate cartilage is thinned or no longer visible. Types I and II are thought to result from shearing forces, whereas type V is attributed to compressive forces [7]. As with Salter–Harris injuries, type V lesions are usually diagnosed retrospectively after premature physeal closure has occured, resulting in acetabular dysplasia and lateral subluxation of the femoral head. Consequently, type V injuries carry a poorer prognosis than other lesions, particularly in children younger than 10 years who are at greater risk of growth arrest and require longer-term follow-up [7]. More recently, Dong et al. [2] expanded the Bucholz classification by adding two additional injury patterns. Type IV is a vertical fracture traversing the triradiate cartilage and extending into both adjacent osseous structures. Type VI corresponds to an osseous bridge adjacent to the triradiate cartilage, resulting from ossification of either an intrapelvic hematoma or hypertrophic callus [4]. However, this modified classification has not yet gained universal acceptance.

To our knowledge, only two cases of acute injury of the triradiate cartilage following a low-energy trauma have been reported [3, 4]. The first involved an obese 13-year-old boy who sustained a complete injury of the triradiate cartilage while playing football [3]. The second involved a 14-year-old boy who sustained a similar injury while running, associated with an ipsilateral ischial tuberosity avulsion fracture [4]. In both cases, the patients were unable to bear weight. The diagnosis was confirmed by CT, and conservative treatment, including traction and immobilization, resulted in an uncomplicated recovery. Ergen et al. [8] also reported triradiate cartilage injury in the absence of acute trauma, related to overuse in sports. Radiography demonstrated unilateral widening of the triradiate cartilage, whereas MRI showed fluid-signal intensity within the triradiate cartilage associated with T2 hyperintensity in the adjacent metaphyseal equivalents. The present case represents the first reported isolated injury of the triradiate cartilage following low-energy trauma. Clinical symptoms were relatively mild. Because the contralateral

triradiate cartilage was fused and the injured triradiate cartilage was already partially fused, conservative management was considered appropriate, as growth-related complications were no longer expected.

Conclusion

Acute traumatic injuries of the triradiate cartilage are exceptional in children outside the setting of high-energy trauma. Nevertheless, similarly to apophyseal avulsion fractures, they should be suspected in young athletes presenting with acute hip pain whenever the triradiate cartilage remains partially or completely open, even unilaterally. When clinical and/or radiographic findings are suggestive, pelvic MRI is valuable for establishing the diagnosis whereas CT remains essential for confirming the fracture and accurately delineating its extent with multiplanar and three-dimensional reconstructions. A fat-suppressed isotropic three-dimensional T2-weighted sequence may also represent a promising non-ionizing alternative to CT for confirming the diagnosis in young children.

Declarations

Author Contribution

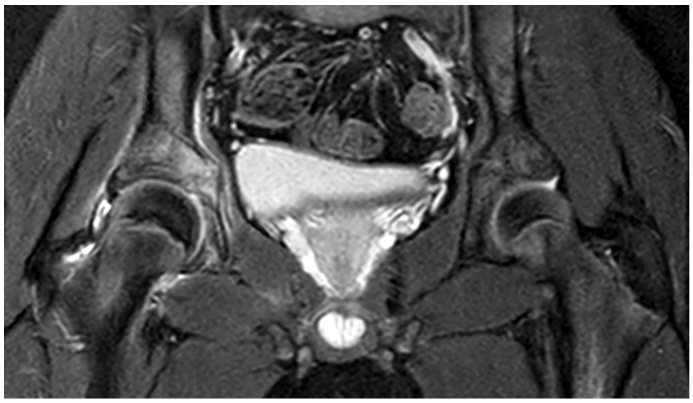
N.B., S.A. and L.K. wrote the main manuscript text. N.B. prepared figures 1 - 4. All authors reviewed the manuscript.

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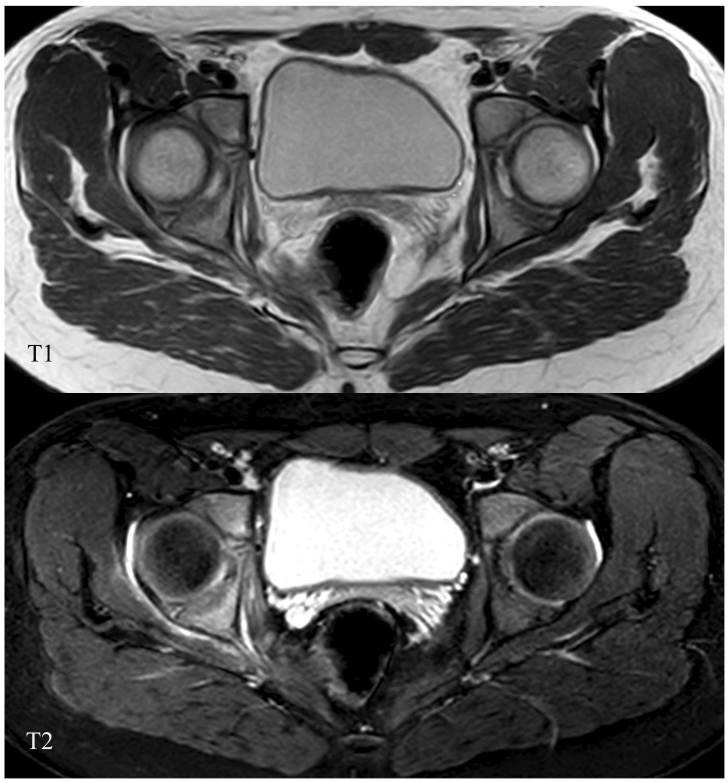
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Figures



a



b

Figure 1

MRI. Coronal T2-weighted STIR image **(a)** demonstrates bone marrow edema on both sides of the right triradiate cartilage. A right hip joint effusion and adjacent soft-tissue edema are also present. Axial T1-weighted and T2-weighted STIR images **(b)** confirm widening of the right triradiate cartilage compared with the contralateral side.

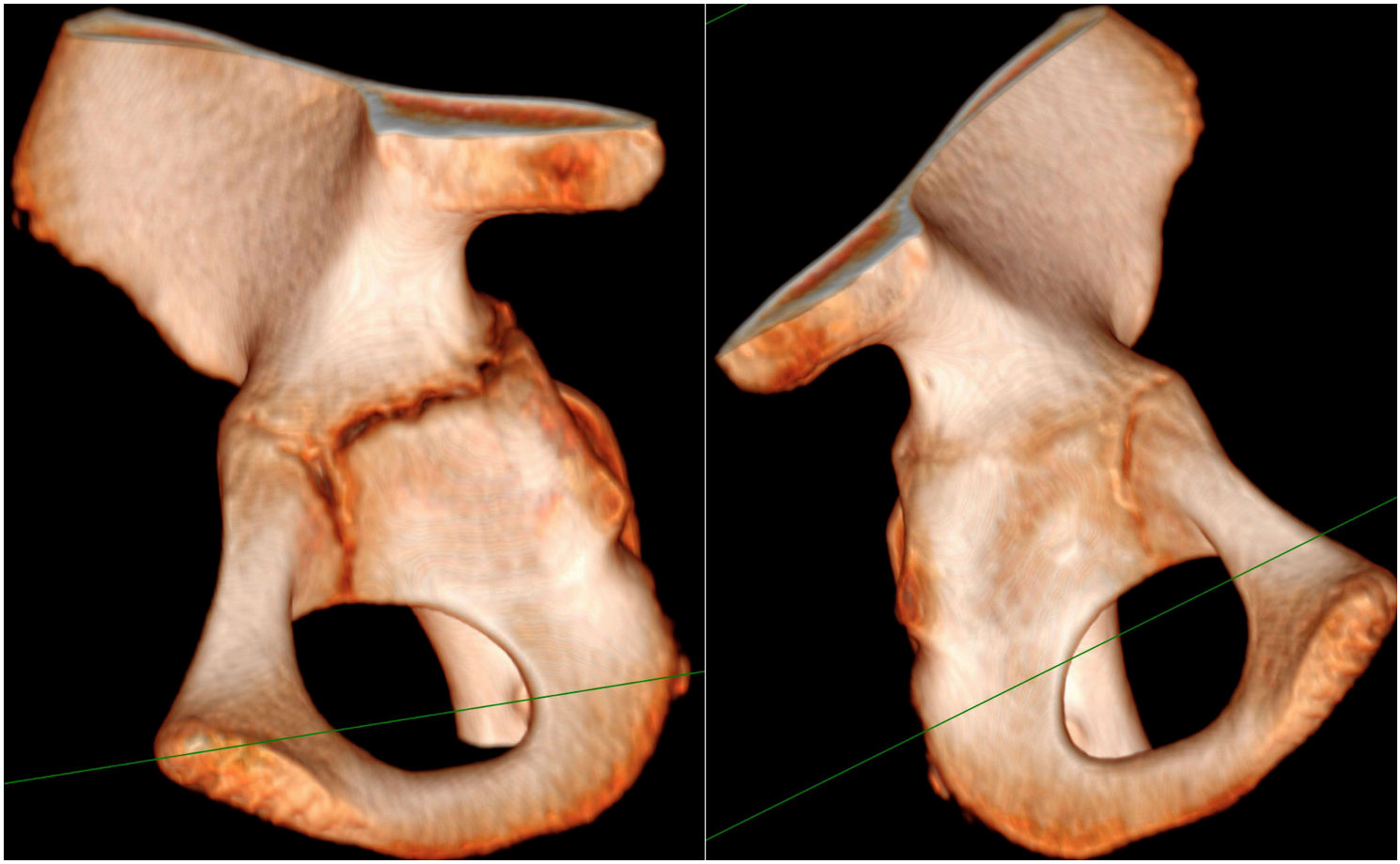


Figure 2

CT. Three-dimensional CT reconstructions demonstrate widening of the posterosuperior limb of the right triradiate cartilage, corresponding to the ilioischial synchondrosis. The physeal separation extends into the proximal portion of the vertical limb, corresponding to the ischiopubic synchondrosis. Note the complete closure of the triradiate cartilage on the contralateral side.

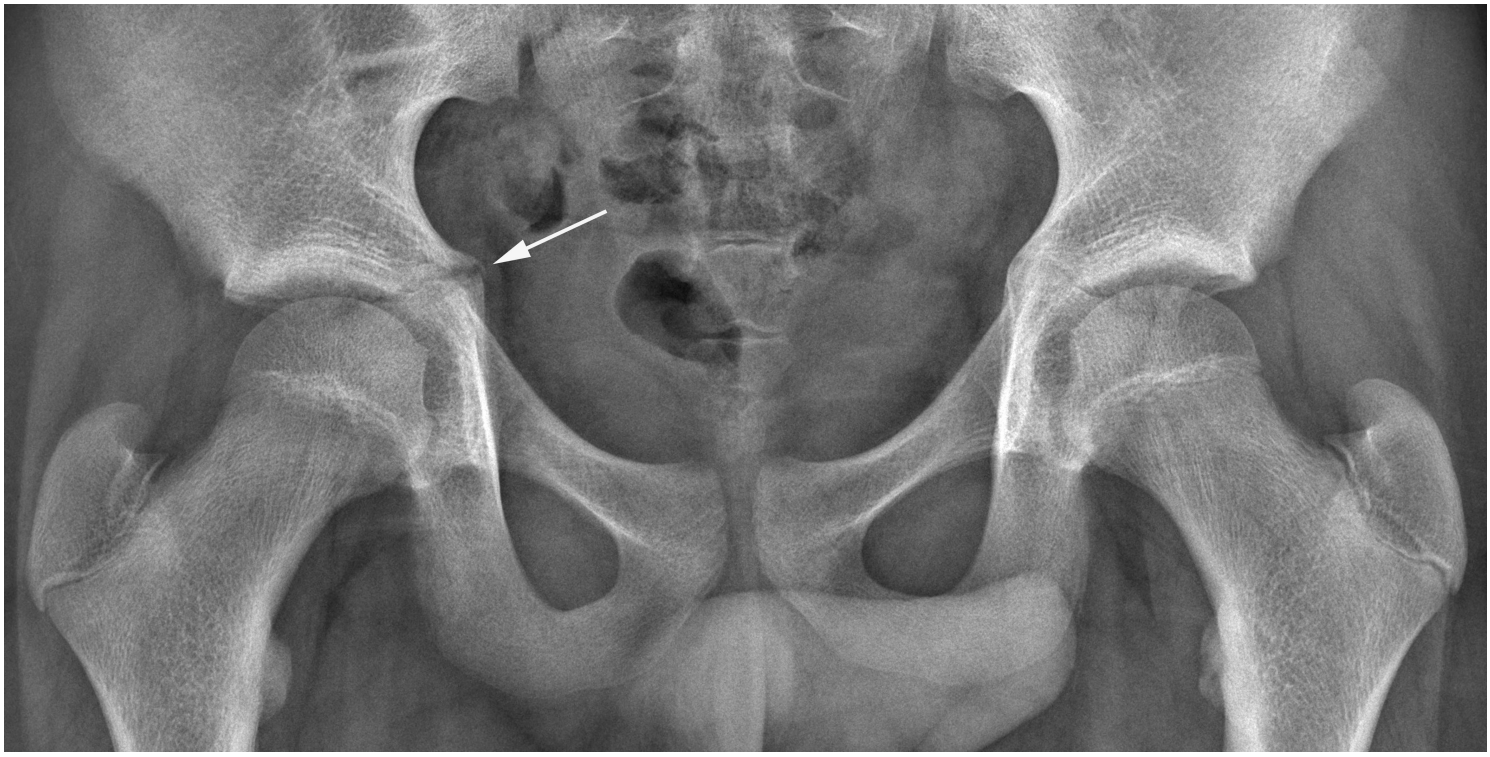


Figure 3

Radiograph. Anteroposterior pelvic radiograph demonstrates widening of the right triradiate cartilage and early intrapelvic callus formation (arrow). Note the asymmetric closure of the triradiate cartilages.



Figure 4

Follow-up MRI. Coronal fat-suppressed T2-weighted image **(a)** demonstrates persistent bone marrow edema adjacent to the triradiate cartilage and fluid-signal intensity within the cartilage. The adjacent soft-tissue edema and right hip joint effusion have resolved. Sagittal fat-suppressed T2-weighted image **(b)** clearly demonstrates widening of the ilioischial synchondrosis extending to the acetabular articular cartilage.