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ORIGINAL ARTICLE

Little Leaguer's shoulder (proximal humeral epiphysiolysis): MRI findings in four boys

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Abstract
Background Shoulder pain is a common problem among adolescent athletes. A possible cause of such pain that can be diagnosed on MRI is a stress injury to the proximal humerus known as Little Leaguer's shoulder (proximal humeral epiphysiolysis).
Objective Our objective was to describe the MRI appearance of Little Leaguer's shoulder.
Materials and methods Four patients (all boys; age range 11–15 years; median 13 years) with clinical, plain radiographic, and MR imaging findings of Little Leaguer's shoulder were studied retrospectively.
Results MRI demonstrated focal physeal widening in all four boys with extension of physeal signal intensity into the metaphysis on T1-weighted and gradient echo coronal and sagittal sequences. T2-weighted sequences were of limited use in demonstrating the physeal widening, which is critical to the diagnosis. Abnormal high T2-signal intensity was seen in the metaphysis adjacent to the focal physeal widening in all the boys.
Conclusion Focal extension of normal physeal T1-weighted and gradient echo signal intensity into the adjacent metaphysis is a sign of stress injury in the proximal humeral physis (Little Leaguer's shoulder). Children should suspend the offending sport to allow healing.

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Introduction

Little Leaguer's shoulder is a stress-related injury to the proximal humeral physis encountered in adolescent athletes participating in sports requiring overhead activity. It is most commonly seen in young baseball pitchers. It was first described by Dotter [1] in 1953 in a Little League pitcher as a "fracture through the epiphyseal cartilage of the proximal humerus." Since then, various terms have been applied to this disorder in the literature, including osteochondrosis of the proximal humeral epiphysis [2], stress fracture of the humeral epiphyseal plate [3], and rotational stress fracture of the proximal humeral epiphyseal plate [4]. The variety of terms attributed to this injury can be confusing, and indeed the widely used term "proximal humeral epiphysiolysis" is potentially misleading because it could imply a separation of the epiphysis from the proximal humeral shaft or a fracture through the epiphysis itself, neither of which is expected with this condition. In this article, Little Leaguer's shoulder specifically refers to stress on the proximal humeral physis or the immediately adjacent metaphysis in the adolescent athlete.

Patients typically present between the ages of 13 and 16 years. In the largest clinical study to date, Carson and Gasser [5] described 23 patients with Little Leaguer's shoulder. They found an age range of 11–16 years, with a mean of 14 years. Of their patients, 91% complained of a gradual onset of pain localized to the proximal humerus encountered during the act of throwing [5]. On physical examination, 87% of their patients had tenderness to palpation over the proximal humerus, and 26% had weakness in external rotation [5].

Although the diagnosis of Little Leaguer's shoulder can often be made on clinical grounds alone, MRI can also play an important role in distinguishing the causes of pain in some patients—particularly those in whom another injury or superimposed injury is suspected based on the clinical history or the physical examination findings. Even when Little Leaguer's shoulder is the suspected clinical diagnosis, a confirmatory MRI is sometimes also obtained when, in the judgment of the treating physician, additional patient or care-giver reassurance is needed or when an MRI would likely have a salutary effect on compliance with conservative therapy. This latter scenario can be especially true in competitive settings where the impetus for continued sports participation can be quite strong.

We have evaluated four patients with Little Leaguer's shoulder by MRI. Our purpose was to describe the MRI appearance of Little Leaguer's shoulder and to compare our observations with other reports of physeal injuries. We review the literature to explain the relationship between the stress injury and the presence of physeal widening that is observed in all reported cases.

Materials and methods

This study was a retrospective observational study for which our institutional review board did not require informed consent, although approval for image and chart review was obtained.

Our patient population comprised a total of four adolescent male athletes (age range 11–15 years; mean age 13 years) who were seen between May 2003 and August 2005 in either orthopedic or physical medicine and rehabilitation clinics. Three of the boys were baseball pitchers and one was a competitive tennis player. All the boys presented to the clinic in-season with complaints of subacute or chronic overuse pain in the region of the proximal humerus of their dominant arm. Three of the four boys had bilateral shoulder radiographs prior to MRI. One of the boys had plain radiographs at an outside institution, with only a report available for review. MRI was performed in all the boys within 10 days (mean 7.7 days) of initial presentation to the clinic. A retrospective review of the conventional radiographs, MRI, and initial reports was performed.

MR imaging was performed on a 1.5-T unit (Siemens Sonata or Avanto, Siemens Medical Solutions, Malvern, Pa.) with a dedicated shoulder coil. All shoulders were studied using our routine non-arthrogram shoulder protocol, which included axial turbo spin echo T1 (TR/TE 470/25), axial turbo spin echo fat-saturated T2 (TR/TE 4,000/105), axial T2* (FLASH), coronal oblique turbo spin echo T1 (TR/TE 606/26), coronal oblique turbo spin echo fat-saturated T2 (TR/TE 3,000/65), sagittal oblique turbo spine echo T1 (TR/TE 504/25), and sagittal oblique turbo spin echo fat-saturated T2 (TR/TE 3,000/45) sequences. One study also included a coronal oblique T2* (FLASH) sequence. Matrix sizes were 384×384 on coronal oblique sequences, 320×320 on sagittal oblique sequences, and 448×448 on axial sequences. Additional scan parameters included a field of view of 280 mm, 4-mm slice thickness, and a 10% interslice gap. A bilateral examination was performed on one of the boys for comparison purposes. All images were reviewed by two fellowship-trained musculoskeletal radiologists and one musculoskeletal fellow in training. Abnormalities in and adjacent to the proximal humeral physis as well as other shoulder pathology were recorded.

A clinical chart review was performed to obtain demographics, type of competitive sport, chief complaint, physical examination findings, initial clinical impression, prescribed treatment, duration of treatment, and outcome.

In all four boys, proximal humeral physeal stress injuries were clinically suspected. Each of the boys underwent MR examination in order to more confidently make the diagnosis and to rule out underlying internal derangement resulting from unclear clinical presentation and examination. In one of the boys a comparison MRI of the contralateral asymptomatic shoulder was requested by the referring physician to further support the suspected clinical diagnosis.

Results

Imaging findings

All four boys demonstrated focal widening of the physis. This was seen consistently on the T1-W oblique sagittal and oblique coronal sequences as a focal extension of the physeal signal into the metaphysis (Fig. 1). One of the boys also had a coronal oblique T2* (FLASH) sequence, which demonstrated this same finding well (Fig. 1). The physis was best delineated on the T2* (FLASH) sequence, compared with the T1-W and T2-W sequences.

All the boys demonstrated high T2-W and low T1-W signal abnormalities within the metaphysis immediately adjacent to the proximal humeral physis (Fig. 2). These metaphyseal abnormalities were best seen in the coronal oblique plane. The signal abnormality in all the boys was hyperintense compared to the growth plate on the fat-saturated T2-W sequences and hypointense on T1-W sequences.

None of the original prospective MRI reports specifically mentioned signal abnormalities in the epiphyses. Retrospective review demonstrated subtle areas of speckled or patchy increased T2-W signal in the epiphyses that are often seen in normal shoulders in children because of variations in marrow composition. We did not find the epiphyseal signal characteristics to be convincingly abnormal or helpful in our

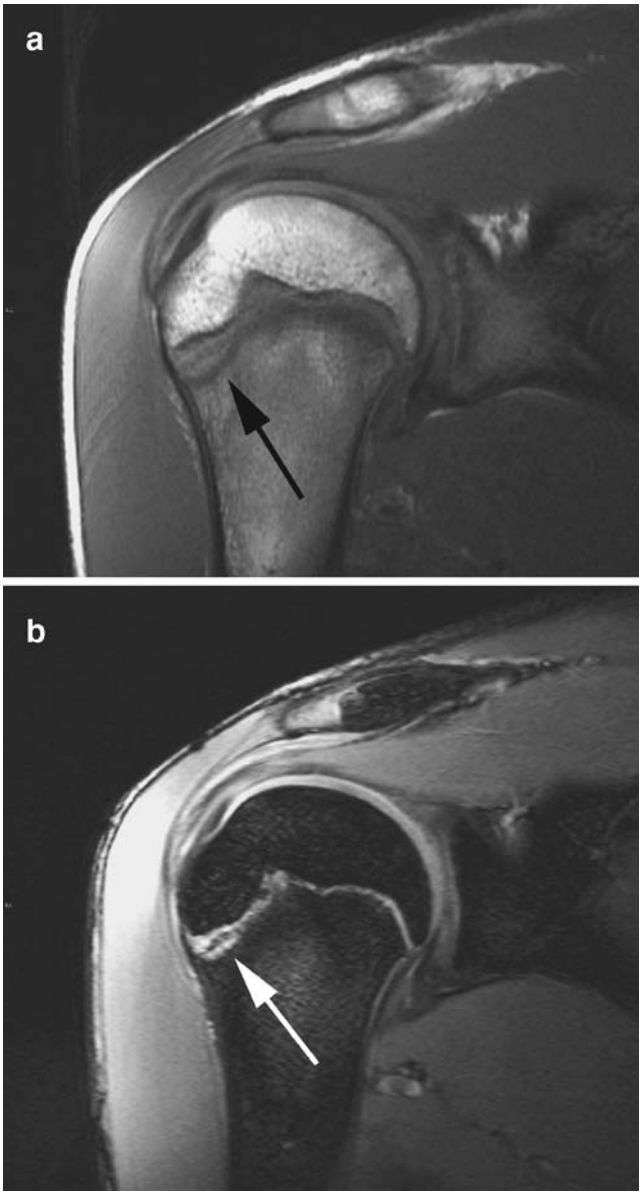

Fig. 1 Images of a 13-year-old male baseball pitcher with 1-month history of right shoulder pain during the playing season. **a** T1-W coronal MR image shows focal widening of the lateral aspect of the proximal humeral physis (*arrow*). **b** Gradient echo coronal MR image shows extension of physeal cartilage signal intensity into the adjacent metaphysis (*arrow*). Physeal cartilage is more conspicuous when compared with the T1-W (**a**) and T2-W (not shown) sequences

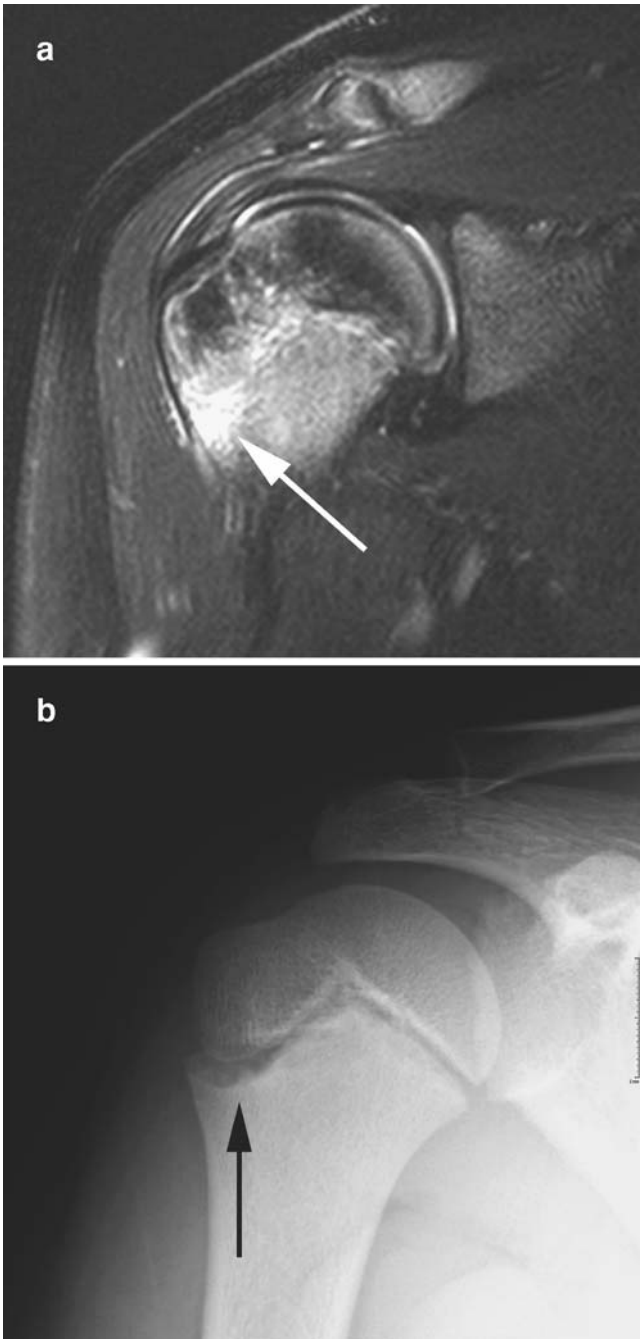

Fig. 2 Images of a 12-year-old male baseball pitcher with 3-week history of right shoulder pain during the playing season. **a** Fat-saturated T2-W coronal MR image shows abnormal high signal in the metaphysis (*arrow*) interpreted as marrow edema. It is adjacent to an area of focal physeal widening demonstrated on T1-W sequences (not shown). **b** Shoulder radiograph shows focal widening of the lateral aspect of the proximal humeral physis (*arrow*)

diagnosis. Periosteal edema and focal cystic changes in the marrow were not observed.

On radiographic studies prior to MRI, two of the four boys had physeal widening and irregularities consistent with Little Leaguer's shoulder (Fig. 2). One boy had equivocal plain film findings. One boy's radiographs were not available for review, but the original diagnostic report mentioned "a Salter I fracture of the proximal humeral physis."

Clinical follow-up

Following clinical examination, plain film evaluation and MRI, all four boys were treated for Little Leaguer's shoulder. All the boys were treated conservatively with specific rest from overhead sports activities for 3 months. Three of the

boys were pain-free at the end of the 3-month lay-off, and all were instructed to gradually resume activity over a period of the next 3 weeks. One of the boys was lost to follow-up.

Discussion

The overall incidence of Little Leaguer's shoulder is not known; however, shoulder pain is commonly encountered in the adolescent athlete participating in sports requiring overhead activity. A study of 298 subjects by Lyman et al. [6] showed that 58% of young baseball pitchers experienced shoulder or elbow pain during the season. The differential diagnosis for shoulder pain in the athlete participating in sports requiring overhead activity is extensive, but Little Leaguer's shoulder should be considered when dealing with an adolescent.

The clinical features of Little Leaguer's shoulder have been described in the sports medicine literature [1, 5, 7]. Frequently, this diagnosis can be made on clinical grounds alone. In certain situations, however, additional imaging by plain film or MRI can prove helpful, such as when a superimposed injury is suspected, when it supports patient compliance with conservative treatment, or when additional patient or care-giver reassurance is needed.

The radiographic findings of Little Leaguer's shoulder have been relatively recently published in the radiological literature by Fleming et al. [8]. They reported that patients with symptoms longer than 3 weeks typically demonstrate lateral physeal widening. Other radiographic abnormalities, reported in the orthopedic literature, include lateral metaphyseal fragmentation, demineralization adjacent to the physis, and sclerosis of the proximal humeral metaphysis [2, 9, 10]. Radiographs, however, are usually normal if symptoms have been present less than 10 days [8].

MRI findings of Little Leaguer's shoulder have been reported by Hatem et al. [11] and Song et al. [12] in the musculoskeletal subspecialty literature in a total of five patients. The predominant findings in these case reports were physeal widening and bone marrow edema on both sides of the physis. Hatem et al. [11] reported adjacent periosteal edema and Song et al. [12] also noted a small subchondral cyst adjacent to the physis in their single case. Our observations differ somewhat from these five published reports, but they are similar to findings described in prior studies of physeal stress injuries at the wrist and knee.

Shih et al. [13] reported MR findings at the distal radial physis in 47 adolescent competitive gymnasts. Their MR findings included horizontal metaphyseal fractures, metaphyseal bone bruises, growth plate widening, and physeal cartilage extension into the metaphysis. Laor et al. [14] reported the MRI appearance of physeal over-use injuries of the knee in six patients. They describe physeal widening with extension of physeal signal intensity into the adjacent metaphysis.

All four of our patients demonstrated at least some focal widening of the physis on the T1-W and GRE sequences, with extension of physeal signal intensity into the metaphysis. All of our patients also demonstrated bone marrow signal abnormality along the metaphyseal side of the physis on both the T1-W and fat-saturated T2-W sequences, which was interpreted as marrow edema.

The mechanics thought to be responsible for this injury have been most thoroughly described in pitchers and occur at different phases of the throwing motion. The most commonly accepted theory to date suggests the mechanism involves repeated torque and possibly distraction on the proximal humeral physis [5]. Torque refers to the external rotational stress applied to the proximal humeral physis during the act of throwing, which is greatest in the late cocking phase of the throwing motion. Distraction refers to the force exerted on the physis created by forward arm motion and the opposing proximally directed force generated by the rotator cuff and encountered at the point of ball release.

It is thought that repeated stress from these torsional and distractive forces during the act of throwing results in injury to the juxtametaphyseal hypertrophic zone, which is the structurally weakest portion of the growth plate [5]. Injury at or near this site can explain the subsequent development of physeal widening, as histological evaluations of child abuse injuries and experiment-induced injuries in animals have demonstrated the development of physeal widening following injury to this region [15–18].

In experiment-induced injury in rabbits, normal endochondral bone formation was disrupted by injury to the metaphyseal blood vessels supplying the physis. This blood supply is required to trigger the normal death of the chondrocytes and mineralization of the matrix in the cartilage. The vascular injury led to prolonged chondrocyte survival, causing extension of hypertrophic chondrocytes into the metaphysis. This correlated with both MRI and plain radiographic findings of widened physeal plates in these animals. After several weeks of follow-up, regrowth of blood vessels from the metaphysis into the physis was observed in these animals, and this also correlated with improvements in physeal widening [17]. Interestingly, in their one reported case of Little Leaguer's shoulder where a follow-up MRI was obtained after conservative therapy, Song et al. [12] also noted an improvement in physeal widening.

We believe that a similar process takes place in over-use injuries of the proximal humerus, where we observed focal widening of the physis in our patients. These findings are similar to previously reported physeal over-use injuries at other anatomic sites (physes of distal radius, distal femur, proximal tibia, and proximal fibula) [13, 14]. All of these injuries likely represent the same pathologic process. In the humerus, repetitive torsional and distractive stress at the proximal physis from overhead activity results in reversible disruption of the blood supply from the metaphysis to the physis, leading to chondrocyte proliferation and physeal widening. Cessation of the inciting physical activity allows regrowth of these vessels and subsequent remodeling of the growth plate toward normal. In our patients, a follow-up radiograph or MRI was considered of limited clinical benefit and was therefore not scheduled.

We also observed ill-defined increased T2-W and decreased T1-W signal abnormality in the metaphysis around the area of focal physeal widening. We believe that this was related to bone marrow edema caused by the local traction effect. We found no convincing epiphyseal signal abnormalities in our patients, but we note that it was reported as a predominant finding in previous case reports by Hatem et al. [11].

In our study, we found oblique coronal and oblique sagittal T1-W and GRE sequences to be the most useful for observing physeal widening. Fat-saturated T2-W sequences best demonstrated the metaphyseal marrow abnormalities that were interpreted as edema around the widened physis. One limitation of our examination is that a coronal oblique gradient sequence was included in only one of our patients and no examinations were performed with administration of contrast agent. Jaramillo et al. [19] have reported on the benefit of contrast-enhanced fat-saturated T1-W sequencing.

Treatment consists of relative rest from throwing for an average of 3 months, while using ice and analgesic medications for pain [5]. Cardiovascular conditioning is encouraged and return to strengthening exercises begins when the patient becomes pain-free. Evaluation of the patient's throwing mechanics is also encouraged [20].

Conclusion

Little Leaguer's shoulder is a relatively common disorder whose diagnosis in certain cases benefits from confirmation by radiographs or MR imaging. As such, the general radiologist should be familiar with the imaging findings in this disorder. MR imaging likely allows earlier diagnosis compared with radiography and should be considered in patients suspected of having Little Leaguer's shoulder in whom additional shoulder pathology is suspected or in whom additional imaging would improve compliance with a conservative treatment regimen or provide additional needed reassurance.

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