Magnetic resonance imaging of direct or indirect injuries to the anterior knee in athletes

Poster No.: P-0011  
Congress: ESSR 2013  
Type: Scientific Exhibit  
Authors: P. Melloni, M. T. Veintemillas, A. Marin, N. C. Lugo Doncel, C. Spinu, R. Valls; Sabadell/ES  
Keywords: Musculoskeletal system, MR, Education, Trauma  
DOI: 10.1594/essr2013/P-0011

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Purpose

To describe and illustrate the MRI findings in direct and indirect traumatic anterior knee lesions in athletes, principally young people participating in basketball, hockey, track and field, football, soccer, and skiing, with previously negative findings on X-ray and/or CT studies.
Methods and Materials

We selected patients with direct or indirect anterior knee lesions from sports trauma studied at our center in 1.0T or 1.5 MRI scanners during the last five years. The MRI protocol in all cases included sagittal and coronal spin-echo or fast spin-echo proton-density and T2-weighted sequences as well as axial gradient-echo and sometimes spin-echo T1-weighted sequences. STIR or fat-suppressed T1-weighted sequences were also used in all cases. We administered intravenous gadolinium contrast agents only when absolutely necessary. All studies were interpreted by two experienced radiologists working independently.

We describe and illustrate the MRI findings that enabled the correct diagnosis in cases in which previous X-ray and/or CT findings were normal.
Results

Anterior knee trauma is relatively frequent in athletes, especially those participating in high risk sports and in those in suboptimal physical condition, such as children participating in school sports and veteran athletes.

Trauma to the anterior knee can result in direct or indirect injury to osseous structures such as the patella, femur, or tibia or to non-osseous structures such as the quadriceps and patellar tendons and/or soft tissues around the patella. Although X-rays, complemented with CT if necessary, are the first imaging examination for traumatic anterior knee injuries, MRI is the gold standard for evaluating occult osseous and soft-tissue lesions of the anterior compartment of the knee. We classify anterior knee lesions into two categories: osseous and non-osseous.

OSSEOUS:

We selected cases of traumatic bone injury where there was no X-ray and/or CT evidence of fracture. In some cases, we studied the knee with MRI when CT findings were indeterminate or to obtain more information about the surrounding soft tissues accompanying osseous knee injury. Thus, we comment on stress fractures, traumatic fractures, and bruised bones detected on MRI.

Stress fractures and traumatic fractures of the knee

A stress fracture is a tiny crack in a bone that usually happens from overuse. Putting repetitive strain on bones can break them down (Fig. 1 on page 10). Resting gives bones a chance to rebuild, the way muscles do. Athletes of all ages participating in football, tennis, track and field, gymnastics, and basketball are very susceptible to stress fractures. In all these sports, the repetitive stress of the foot striking the ground can cause trauma. Without sufficient rest between workouts or competitions, an athlete is at risk for developing a stress fracture. Stress fractures are more common in female athletes (Fig. 2 on page 10).

Bruised knee bone

Sprains and strains are among the most common injuries incurred while playing sports. Sports injuries including bruises, sprains, and strains can be caused by minor trauma that involves ligaments, muscles, and tendons. Bone marrow contusions are frequently identified at MRI after a direct or indirect injury to the knee.
The severity of bone bruising depends directly on the energy of the impact. Contact injuries (the athlete is hit by another player or falls and makes contact with the ground) have more energy behind them than noncontact injuries. Bone bruises are classified into five types on the basis of their architectural appearance and relationship to cortical bone: reticular, geographic, linear, impaction, and osteochondral.

These osseous injuries may result from a direct blow to the bone, from compressive forces of adjacent bones impacting one another, or from traction forces that occur during an avulsion injury. The distribution of bone marrow edema is like a footprint left behind at injury, providing valuable clues to the associated soft-tissue injuries.

Five contusion patterns with associated soft-tissue injuries occur in the knee: pivot shift injury, dashboard injury, hyperextension injury, clip injury, and lateral patellar dislocation. The pivot shift injury results in the classic bone marrow edema pattern involving the posterolateral tibial plateau and the mid-portion of the lateral femoral condyle. The dashboard injury results in edema in the anterior aspect of the proximal tibia. Hyperextension results in the "kissing" contusion pattern involving the anterior aspect of the proximal tibia and distal femur (Fig. 3 on page 11). The clip injury results in a prominent area of edema involving the lateral femoral condyle and a smaller area of edema involving the medial femoral condyle. Finally, lateral patellar dislocation results in edema involving the inferomedial patella and anterior aspect of the lateral femoral condyle (Fig. 4 on page 12). A direct hit in a vigorous sport like football can provoke edema involving the patella and anterior margin of the tibia with preservation of the adjacent soft tissues such as ligaments (Fig. 5 on page 13). In many instances, the mechanism of injury can be determined by studying the distribution of bone marrow edema, which then makes it possible to accurately predict the specific soft-tissue abnormalities likely to be present.

Osteochondral lesions

Osteochondral fractures of the patella are common, especially in adolescents and athletes. They can be caused by impact or direct blow, avulsion, or shearing forces caused by traumatic patellar dislocation. The patella dislocates laterally and the medial side of the patella may hit the anterior aspect of the lateral femoral condyle. This may cause a fracture at the point of contact that includes an articular cartilage or subchondral bone of the patella or the femoral condyle. A loose body with an osteochondral lesion at the articular facet of the patella after dislocation from a direct hit over the knee is fairly common in athletes with traumatic anterior knee injury (Fig. 6 on page 14).

Osteochondral fractures of the patella are associated with acute dislocation of the patella. Less frequent than a bruised patella after patellar dislocation, osteochondral fracture in patellar dislocation affects the medial facet of the patella (Fig. 7 on page 15).
NON-OSSEOUS:

Injuries to non-osseous knee structures are common in athletes of all ages. In this study, we selected injuries to soft-tissue structures of the anterior knee compartment resulting from direct or indirect trauma in athletes, such as tendinopathy, tendon tears, cartilaginous lesions, and other soft-tissue lesions.

Overuse tendinopathies are common in skeletally mature athletes, occurring in up to 20% of jumping athletes. Adolescents who participate in sports like football, basketball, soccer, ballet, and gymnastics tend to get Osgood-Schlatter disease and, less frequently, Sinding-Larsen-Johansson disease. Boys 11 to 15 years old and girls 8 to 13 years old are at greater risk. Adolescents develop this problem because their bones grow faster than their tendons and muscles, causing the muscles and tendons to stretch and tighten. The incidence of overuse injuries in young athletes is on the rise.

Osgood-Schlatter disease

Therefore, children who regularly participate in sports that involve jumping much of the time, such as athletics (particularly the high jump), basketball, volleyball, gymnastics, jogging, and football, can exert much pressure on the knees. Pain will be exacerbated by exercise (especially distance running and jumping), squatting, stair climbing, and stretching the quadriceps. Physical examination shows marked tenderness at the tibial tubercle, often with a bony prominence with swelling of overlying soft tissues. The quadriceps and hamstrings are invariably tight and there may be intercurrent PF malalignment and anterior knee pain.

This condition occurs at the level of the tibial tuberosity, where the patellar tendon inserts. This area is particularly fragile due to local growth phenomena and because the patellar tendon is subjected to multiple and repeated trauma that causes microavulsion. Osgood-Schlatter disease produces a true avulsion of cartilaginous fragments of the tuberosity, drawn up through the tendon (multiple and repeated thrusts of the tendon). Fragmentation of the tubercle and inflammatory changes in the adjacent tendon are typical findings that can persist into adulthood. The pathology is also well demonstrated on MRI as thickening of the distal patellar tendon with variable increase in signal intensity on T1-weighted, T2-weighted, and gradient-echo sequences, with hypertrophy and/or fragmentation of the tibial tubercle and heterotopic ossification within the distal patellar tendon (Fig. 8 on page 16).

Sinding-Larsen-Johansson disease

This is the same process but occurring at the lower pole of the patella. The imaging characteristics are similar, affecting the proximal tip of the patellar tendon where it inserts.
into the inferior pole of the patella (apical ossification center). This disease mainly affects children aged 10 to 13 years, who typically present mechanical pain during exercise. MRI can reveal increased T2-weighted signal intensity for edema in the proximal aspect of the patellar tendon, sometimes with adjacent patellar edema, if reactive (Fig. 9 on page 17).

**Patellar tendinopathy**

Also known as "jumper's knee", this is one of the most common injuries in the sports world, especially in physical activities that require constant movement, turns, and jumps, such as cycling, athletics, tennis, or basketball.

However, other sports in which patellar tendinitis is not as common are seeing an increase in cases; for example, fitness plyometrics in football leads to high knee stress. Using the wrong shoes for sports can cause this disease.

Overuse of the tendon results in inflammation (acute) and degeneration (chronic) that can lead to tearing. The characteristic symptoms are localized pain anterior to the patella that is aggravated by activity and that increases with efforts and may or may not calm with rest, infiltration, and localized crepitus.

**Quadriceps tendinopathy**

Sports like volleyball, basketball, running, football, and snow skiing that involve jumping and impact systematically overload the quadriceps tendon, causing inflammation. Injury to the quadriceps tendon can also occur in cycling due to poor positioning on the bike when the saddle is too low or too far forward.

On MRI, acute tendinitis of the patellar or quadriceps tendon is usually seen as focal or diffused thickening with increased signal intensity on T2-weighted or STIR images of a portion or all of the patellar tendon, often the proximal third (Fig. 10 on page 18) or the distal insertion of the quadriceps tendon at the proximal pole of the patella (Fig. 11 on page 19). Chronic tendinitis of the patellar tendon shows thickening with heterogeneous signal intensity on all sequences, especially T1-weighted and T2-weighted sequences (Fig. 12 on page 20).

**Partial tendon tears**

The patellar and quadriceps tendons can tear completely or partially. Such injuries occur from a strong impact to the knee or during sports that require running or jumping. Partial
ruptures of the patellar and quadriceps tendons are relatively uncommon in acute sports-related injuries. Many tears do not completely disrupt the soft tissue. This is similar to a rope stretched so far that some of the fibers are torn, although the rope remains in one piece. Incompletely discontinuous hypointense signal fibers of the quadriceps (Fig. 13 on page 21) or patellar tendon (Fig. 14 on page 22) on T1-weighted and/or T2-weighted sequences can be detected on MRI.

Complete tendon tears

A complete tear will disrupt the soft tissue into two pieces. Rupture of the quadriceps or patellar tendon is a rare injury in the young athletes, only possible when they receive a high energy blow directly on these tendons in falls or twists. It has great clinical importance as the quadriceps and patellar tendons are the terminal extension of the quadriceps muscle at the patella. The quadriceps or patellar tendon often tears where it attaches to the patella, and it can break a piece of the bone as it tears. Sports injuries can result in acute avulsions at the insertion of the patellar tendon onto the inferior patellar pole and less commonly at its tibial insertion, or the insertion of the quadriceps tendon onto the superior patellar pole (Fig. 15 on page 23). Longitudinal tear of the patellar tendon with interposed edema and/or hemorrhage can be seen in an unprepared athlete thrown off balance (Fig. 16 on page 24).

Chondromalacia patellae

Chondromalacia patella is one of the most common knee injuries in any sport; it is especially common in cyclists and participants in running and jumping sports. Runners that pronate and cyclists with improper bike fit/cleat position are especially at risk.

MRI can demonstrate signal alteration of patella hyaline cartilage as an area of hypointensity on T1-weighted images or hyperintensity on T2-weighted images within cartilage with normal or altered contours, often accompanied by bone reactive changes like osseous edema, cyst formation, and sclerosis, depending on the stages; the last stage is degenerative arthritis, which is a common cause of anterior knee pain (Fig. 17 on page 25).

Prepatellar bursitis

Repetitive trauma from overuse or, more commonly, chronic irritation results in local inflammation and fluid collection within the bursa. This is a progressive condition that can manifest initially due to a variety of situations. In sport, it is common in wrestlers and athletes who have fallen to the ground during in any sport and often do not remember
when. Repeated pressure on the patella, such as kneeling, can cause inflammation and discomfort that contribute to the development of patellar bursitis (Fig. 18 on page 26).

**Hemarthrosis**

Traumatic knee effusion is a relatively common injury secondary to a patellar dislocation, especially in young adolescent boys and females (Fig. 19 on page 27). But ACL tears (40%), patellar dislocations (28%), and isolated meniscus tears (13%) were the most common injuries.
Fig. 1: PATELLAR STRESS FRACTURE. Coronal proton-density MRI in a 44-year-old woman after a fall during a run shows a linear area of decreased signal intensity without reactive osseous edema within the superior pole of the patella (arrow). The lesion was not visible on plain films.

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Fig. 2: TIBIAL STRESS FRACTURE. Sagittal proton-density MRI in a 49-year-old woman, an amateur marathon runner, shows a long linear area of decreased signal intensity without reactive osseous edema within the proximal third of the right tibia (arrow). There was another, identical stress fracture in the contralateral tibia. These lesions were not visualized on the first plain film.

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**Fig. 3:** FEMORO-TIBIAL OSSEOUS BRUISE. Sagittal STIR MRI in a 23-year-old man shows an edematous area caused by bruising at the anterior margin of the medial femoral condyle (short arrow) and medial tibial plateau (long arrow).

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**Fig. 4:** PATELLO-FEMORAL OSSEOUS BRUISE AFTER TRAUMATIC PATELLAR LUXATION: Axial STIR MRI in a 19-year-old woman after a traumatic patellar luxation shows an edematous area caused by a bruise at the medial margin of the patella (short arrow) and at the lateral margin of the lateral femoral condyle (long arrow).
Fig. 5: PATELLO-TIBIAL BRUISE OSSEOUS. Sagittal STIR MRI in a 30-year-old man shows an edematous area resulting from a direct injury at the inferior pole of the patella (short arrow) and anterior margin of the medial tibial plateau (long arrow). Note the traumatic focal tendinitis at the proximal insertion of the patellar tendon (red arrow).

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Fig. 6: PATELLAR CHONDRAL FRACTURE WITH DISPLACED FREE BODY. Axial gradient-echo MRI in a 32-year-old woman after traumatic patellar luxation shows extensive focal cartilage loss (long arrow) with patellar chondral fracture and a medially displaced free body (short arrow).

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Fig. 7: PATELLAR FRACTURE AND FEMORAL OSSEOUS BRUISE AFTER TRAUMATIC PATELLAR LUXATION: Axial gradient-echo MRI in a 32-year-old man after a traumatic patellar luxation shows a displaced fracture at the medial margin of the patella (short arrow) and an edematous area caused by a bruise at the lateral margin of the femoral condyle (long arrow). Note also the partial tear of the medial retinaculum and articular synovitis.

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Fig. 8: OSGOOD-SCHLATTER DISEASE. Sagittal STIR MRI in a 15-year-old schoolboy athlete with persistent anterior knee pain shows thickening of the distal patellar tendon with increased signal intensity together with fragmentation of the tibial tubercle within the distal patellar tendon and adjacent reactive trabecular osseous edema (long arrow). Note the deep infrapatellar bursitis (short arrow).

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**Fig. 9:** SINDING-LARSEN-JOHANSSON DISEASE. Sagittal STIR MRI in an 18-year-old schoolboy athlete with persistent anterior knee pain shows thickening of the proximal patellar tendon with increased signal intensity together with fragmentation of the distal pole of the patella and adjacent soft-tissue edema (arrow).

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Fig. 10: ACUTE PATELLAR TENDINITIS. Axial gradient-echo MRI in a 41-year-old male handball player with acute anterior knee pain and tumefaction shows a focal thickening with increased signal intensity at the proximal level of the patellar tendon (arrow).

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Fig. 11: ACUTE QUADRICEPS TENDINITIS WITH PATELLAR BRUISE. Sagittal STIR MRI in a 42-year-old male soccer player after indirect trauma to the knee shows edema within the quadriceps tendon and in the surrounding soft tissues at the suprapatellar level (long arrow), accompanied by an osseous bruise at the proximal pole of the patella (short arrow).

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Fig. 12: CHRONIC PATELLAR TENDINITIS. Axial gradient-echo MRI in a 40-year-old male cyclist with anterior knee pain and tumefaction shows a fusiform thickening with diminished signal intensity at the trajectory of the patellar tendon (arrows).

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**Fig. 13:** PARTIAL TEAR OF THE QUADRICEPS TENDON. Sagittal T2-weighted MRI in a 32-year-old male basketball player with acute anterior knee pain and tumefaction after a violent jump shows a longitudinal thickening with increased signal intensity at the suprapatellar level of the quadriceps tendon (arrows), without distal avulsion.

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**Fig. 14:** PARTIAL TEAR OF THE DISTAL PATELLAR TENDON Sagittal proton-density MRI in a 33-year-old male soccer player with acute anterior knee pain after indirect trauma to the knee shows an incomplete tear of the patellar tendon at the infrapatellar level with avulsion (arrow).

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Fig. 15: COMPLETE TEAR OF THE QUADRICEPS TENDON. Sagittal T2-weighted MRI in a 48-year-old man, an amateur marathon runner, after a casual fall and indirect strike over the knee during a run shows a complete tear at the distal insertion of the quadriceps tendon; a residual tendon is seen at the proximal pole of the patella (arrow). Note also the prepatellar bursitis.

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**Fig. 16:** LONGITUDINAL TEAR OF THE PATELLAR TENDON: Sagittal proton-density MRI in a 29-year-old male jumper shows a longitudinal tear of the patellar tendon (arrow) without proximal or distal avulsion. Note also the patellar (short arrow) and deep infrapatellar (asterisk) bursitis.

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Fig. 17: CHONCROMALACIA PATELLAE. Axial STIR MRI in a 17-year-old girl, a sporadic cyclist, after traumatic patellar luxation shows extensive focal cartilage loss (long arrow) with small chondral lesions and osseous bruise in the medial patella (short arrow). Note the articular synovitis.

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Fig. 18: PREPATELLAR BURSITIS. Axial STIR MRI in a 33-year-old sportswoman with a slow-growing prepatellar mass seven days after a fall during a run shows a cystic prepatellar mass (arrow).

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**Fig. 19:** HEMARTROSIS. Axial gradient-echo MRI in a 29-year-old female basketball player after traumatic patellar luxation shows a fluid-fluid level collection between the patella and the femur (long arrows). Note the osseous bruise at the lateral margin of the lateral femoral condyle (short arrow).

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Conclusion

MRI is an ideal noninvasive method for evaluating patients with direct or indirect injury to the anterior knee when X-rays and/or CT findings are negative or inconclusive. The spectrum of MRI findings in direct or indirect traumatic injuries to the knee helps to establish the correct diagnosis and to orient treatment.
References


