Quadriceps Muscle Injury

Aleksi Jokela and Lasse Lempainen

Contents

Abstract

Quadriceps muscle injuries are common in sports involving kicking and rapid movements, such as sprinting, jumping, or changing direction. Patient history, clinical examination, and magnetic resonance are crucial things in diagnostics. It is essential to differentiate, if the injury is in tendon or in muscle. Indirect quadriceps injury mechanisms, such as kicking and

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sprinting, typically affect the rectus femoris. Direct contusions typically cause injury to the vastus muscles. Most of the quadriceps injuries are treated conservatively with good results. However, there are several indications for operative treatment, such as quadriceps tendon rupture or complete proximal rectus femoris avulsion with clear retraction. In professional athletes, surgical treatment is recommended more often.

Keywords

Quadriceps · Muscle · Tendon · Injury · Rectus femoris · Vastus lateralis · Vastus medialis · Vastus intermedius

Epidemiology

Quadriceps muscle injuries are common in sports requiring kicking and sprinting, especially in football in its different forms. In soccer, quadriceps is one of the main affected muscle groups either with injuries and recurrences, the rectus femoris being the most commonly involved muscle in quadriceps injuries [1]. They are the third common muscle injuries, as only hamstring and groin injuries are more common. They account for 5% of all injuries to footballers and 19% of all muscle-tendon injuries [1]. The vast majority of these injuries affect the proximal free tendon, myotendinous junction (MTJ), and intramuscular tendon [2].

Fact Box 1
Quadriceps muscle injuries are common in sports requiring kicking and sprinting, especially in football in its different forms.

Specific Anatomy

The quadriceps femoris muscle group consists of four muscles located on the front of the thigh: rectus femoris, vastus medialis, vastus lateralis, and vastus intermedius. The rectus femoris has two origins: the direct head originates from the anterior-inferior iliac spine (AIIS), and the indirect head arises from the superior acetabular ridge and the posterolateral aspect of the hip joint capsule [3]. The recent study has shown that also a third membranous origin of the rectus femoris exists [4]. The two tendons form a conjoined tendon approximately 2 cm distally from their origin, the direct head being on the superficial part [3]. After the conjoined tendon, the direct head continues distally on the superficial part of the muscle, and the indirect tendon extends intramuscularly continuing about two thirds of the muscle length. The structure of the muscle fibers of the direct head is unipennate, whereas the muscle fibers of the indirect head have origins on both the medial and lateral borders of the tendon, forming a bipinnate structure [3]. Vastus muscles originate from the proximal part of the femur [5]. Distally, all four quadriceps muscles fuse and form a tendon (quadriceps tendon) surrounding the patella and attaching to the tibial tuberosity.

The rectus femoris has a high proportion of type II muscle fibers, which produce powerful, explosive movements with quick changes in muscle length during contraction [6].

Biomechanics

The main function of the quadriceps femoris is the knee extension. The rectus femoris has also function as a hip flexor, and the vastus muscles offer support to the patella. The vastus medialis also works as adductor, extensor, and external rotator of the thigh. The quadriceps femoris is innervated by the femoral nerve (L2–L4) [7].

During running gait cycle, the quadriceps muscles are active from the late swing to midstance as they are preparing the leg for ground contact and to absorb the force from the impact during stance phase [8]. The quadriceps muscles are working eccentrically, as the knee flexes. In the second half of the stance phase, as the knee starts to extend, the quadriceps begin to contract concentrically and generate power. The rectus femoris is only quadriceps muscle being active in mid-swing, as it is preventing the posterior movement of the tibia as the knee flexes. In early swing, it also contracts eccentrically to prevent excessive knee flexion.

Etiology

Risk Factors

The most likely intrinsic risk factors for quadriceps muscle injuries are previous muscle injuries at the thigh area, short height, dominant leg, and poor knee extensor flexibility and strength [9, 10]. The extrinsic risk factors include a dry playing field.

A previous history in the same muscle is the greatest risk factor also for other muscle injuries, such as hamstring [11]. Both rectus femoris and hamstring muscles have a high proportion of type II muscle fibers, which are also known as fast muscle fibers as they actively participate in powerful contractions and explosive movement. That may be among the reasons these muscles often get injured during sprinting, jumping, or kicking, which are activities demanding extreme power and speed. The biarticular nature may also predispose the rectus femoris to injuries, as it crosses to big joints, hip, and knee. The risk of reinjury in rectus femoris is about 17% [9].

Despite the fact that generally muscle injuries are more common in older age, there is no association between age and quadriceps muscle injury [1, 11, 12]. Shorter athletes have a higher risk of rectus femoris injury, but high body weight is not a significant contributing factor for injury, although this has been suggested [11–13].

Injury Mechanism

Muscle strain injuries usually occur during eccentric function of the muscle [14, 15]. Injuries to the quadriceps femoris typically occur in sports including sprinting, jumps, and kicking [9], which require eccentric quadriceps muscle action.

The most common mechanism of quadriceps muscle injury in football is kicking [16, 17]. Kicking movement requires a powerful eccentric contraction of the quadriceps muscles, especially the rectus femoris. In the beginning of the kicking movement (back-swing phase), the rectus femoris works eccentrically to decelerate hip extension and knee flexion [18]. After that, the hip starts to flex as the knee is still flexing, while the rectus femoris is working eccentrically to prevent excessive knee flexion (forward-swing phase). Then the angular velocity starts to increase in both thigh and lower leg until the ball contact, during of which the knee is in extension. The most likely moment of the rectus femoris injury during kicking is the forward-swing phase, when thigh and lower leg have great angular velocities and the knee is still flexed [9]. However, also ball contact and ground contact phase have been suggested to be the crucial moments for rectus femoris injuries during kicking [19–22].

Quadriceps muscle injuries are also typical during sprinting, especially in acceleration or deceleration. It has been suggested that high angular velocities of the hip and knee combined with powerful eccentric contractions predispose quadriceps muscles to injury [9]. The rectus femoris reaches its maximal length at the beginning of the swing phase, as the hip flexors generate force and the knee extensors simultaneously absorb energy through an eccentric muscle function [23]. In sports like football, players have to repeatedly change directions, decelerate and stop rapidly. In deceleration, the trunk is positioned in a more erect posture and posterior lean, which moves the center of mass posterior to the base of support. This causes extra braking forces and eccentric force on the quadriceps, and the time over which these forces must be absorbed is short. This leads quadriceps muscles prone to injury.

In addition to indirect injuries caused by kicking or sprinting, quadriceps muscle injuries can occur due to direct contusions. Quadriceps contusion injuries usually result from an external blow during contact with another player or objective. These injuries are also called “Charley horse” or “dead leg.”

Fact Box 2
The most typical quadriceps muscle injury mechanisms are kicking and sprinting, which require rapid eccentric muscle function. Quadriceps contusion injuries are also possible due to external blows, these are called “Charley horse” or “dead leg”.

Diagnosis

Classifications

Formal classification systems for grading quadriceps femoris injuries are lacking. However, several muscle injury classification are generally used, Munich, ISMuLT, and British muscle injury classifications as examples [24–26]. They include injury mechanism, locations, severity, and recurrent injuries. In terms of severity, grade I injuries are mild injuries with a small damage to the structure of the musculotendinous unit with minor swelling and discomfort. These injuries have no or only minimal deficit in strength and function. Grade II injuries are partial tears of the musculotendinous unit, which involve a clear loss of strength and function. Grade III injuries are classified as complete ruptures, resulting in a total lack of muscle strength and function. Quadriceps muscle injuries are classified based on the muscle (s) involved. Especially rectus femoris injuries are classified based on the location: proximal, mid-substance, and distal [27]. As mentioned in the anatomy section, the rectus femoris has quite complex anatomy with versatile tendinous structures, and that should be taken into consideration when assessing the correct treatment. The injury can be located in muscular area, or it can be primarily affecting the tendon, such as the central tendon of the rectus femoris [28]. Sometimes, the injury can be located between the muscle and tendon, in the myotendinous junction (MTJ). The accurate diagnosis requires the information whether the injury is complete or partial, the amount of tendons involved, and the amount of tendon retraction [29].

Physical Examination

Before physical examination, it is important to know the mechanism and location of the injury. It is also essential to know the anatomy of the anterior thigh and construction of the quadriceps muscle group. In addition to complex injuries, the injury can be located only in the muscle or tendon area.

There is often a palpation pain in the area of injury, and a severe rupture can cause a visible and palpable gap on the skin. If the injury is located in the proximal part of the rectus femoris, hip flexion against resistance is often painful and weak compared to the healthy side [30].

The injury located in the mid-substance or distal area of the quadriceps affects the extension force of the knee [31]. If the tendon of the quadriceps femoris is completely ruptured at the distal part close to the patella, the knee extension against resistance does not often succeed at all [27]. Only very rarely there is a visible bruise on the skin, even though the rupture is complete and severe. In palpation, a chronic rupture of the central tendon of the rectus femoris can feel the same as muscular soft tissue tumor [32].

Fact Box 3
In clinical examination, there is often a palpation pain at the injured area and weakened knee extension and/or hip flexion against resistance.

Imaging

Imaging plays an important role when classifying the quadriceps muscle injuries and assessing the optimal treatment and prognosis [33]. Magnetic resonance imaging (MRI) is the first choice diagnostic method in quadriceps muscle injuries, as it allows the accurate classification and diagnosis of injury in both acute and chronic phases (Fig. 1) [34].

Ultrasound (US) can also be an option in the diagnosis of anterior leg injury. Its advantages are that it is easily available, it is suitable for monitoring the muscle injury healing process, and it can be performed during muscle contraction and movement [35]. However, it is less sensitive to find small injuries, splits, or ruptures in the tendon.

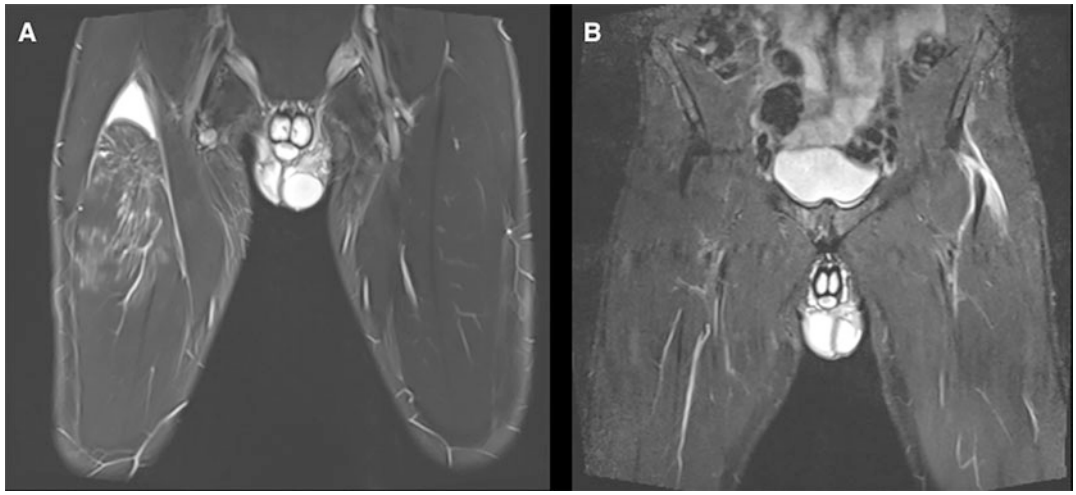

Fig. 1 Two examples of rectus femoris injuries: rupture at the myotendinous junction area in the right leg (**a**) and a left-side rupture of proximal tendinous area (**b**)

Other Diagnostic Criteria

In anterior thigh injuries, the most likely injury type can be concluded based on the mechanism of injury [2]. Similarly to the hamstring injuries, some correlation between injury mechanism and injury type have been found in rectus femoris injuries, but the evidence is limited.

Kicking has been found to be an important mechanism leading to complete rectus femoris ruptures and injuries located at the proximal free tendon [2]. On the other hand, sprinting is the other typical mechanism in rectus femoris injuries but rarely associated with the proximal free tendon injury.

Direct injuries are caused by external forces, during tackling or collisions, and the pain and the injury location is typically on the specific place of the trauma. In these injuries, the most commonly injured muscles are the vastus intermedius, vastus lateralis, and vastus medialis. The energy of the injury, surface of the impact, the angle, and the contraction state of the muscle affect to the severity of the injury.

Prevention

As there is a lack of studies specifically investigating prevention of quadriceps muscle injuries, one prevention strategy is to focus on known risk factors and injury mechanisms and develop prevention programs addressing them. Sprinting and kicking are activities that require great strength in knee extension and hip flexion, and especially kicking requires great flexibility as quadriceps muscles are greatly elongated in peak hip flexion during the swing phase. It has been found that a good functional mobility of the hip reduces the risk of quadriceps muscle injury, especially in sports involving kicking [13]. Quadriceps muscle flexibility training to achieve the optimal levels is crucial and should be implemented in any prevention program to prevent quadriceps injuries.

Versatile fitness training with good balance between the exercise and recovery build the basis for injury prevention. In terms of quadriceps muscle group, eccentric training during preseason can prevent injuries. Additionally, the hip flexion strength is associated with lower risk of rectus femoris injury, and good pelvic control reduces the load on the tendon insertion area, thus decreasing the risk of muscle injury [9]. Therefore, exercises that improve the core control and mobility of the joints and the pelvic area are essential in high-level athletes' training programs. In terms of preventing quadriceps muscle injuries, effective training of hip flexors with hip flexion angles above 90° is recommended [36]. Additionally, knee extension eccentric muscle training should also be implemented to training programs, especially in football players [37].

Conservative Treatment

The choice of treatment, prognosis, and time to return to sport vary depending on the location and severity of the injury [38, 39]. Tendon injuries typically take more time to heal than muscle injuries. The vast majority of quadriceps muscle injuries are treated by conservative means with good results [25, 40].

The conservative treatment is performed following the general guidelines of muscle injury treatment. The healing process of muscle injury can be roughly divided into three phases: (1) inflammatory phase of destroyed muscle fibers (1–3 days), (2) repair of muscle fibers (3–4 weeks), and (3) rearrangement, strengthening, and reformation of muscle fibers (3–6 months) [41, 42].

The extent of the injury and the size of the hematoma is aimed to be minimized immediately at the beginning of treatment by cryotherapy, compression of the injury area, and the use of crutches. The affected muscle is advised to be in rest and elevated position when possible.

Rehabilitative treatment is started early in order to prevent the development of muscle weakness. The ruptured muscle is supported in the early stages by taping or elastic bandage if necessary for the duration of training. It is important not to cause pain to the injured muscle. Passive stretching combined with isometric and eccentric muscle contractions can be started after the acute phase.

Training load is being gradually increased. Already at the initial stage, it is important to activate the compensatory muscles and proceed in stages [25]. Rehabilitation process is carried out progressively with caution [6]. The main thing is to prevent recurrence of muscle injury. After the initial phase of the rehabilitation, the gym exercise can be started. Gym-based exercise must be strictly monitored by healthcare professionals. Progressive loading with respect for biological healing time of the injured area is key to success.

Sport-specific exercises and return to competitive sports are allowed in the final stages of rehabilitation. The rehabilitation must be started early, and load should be increased with control and step by step. It is essential to prevent pain causing activities to avoid reinjuries and setbacks. Muscle strength, mobility, and speed should be close to the pre-injury level before returning to competitive sports [43]. Also, the athlete is advised to be completely symptom-free at the time of return to high-level sport.

Muscle contusions most often heal faster than stretch injuries. Even bigger muscle contusions typically heal well making it possible to return to sports already after 2–3 weeks. The partial muscle and tendon injuries of the proximal rectus femoris heal well with proper rehabilitation in 2–3 months and central tendon injuries in about 2 months.

Surgical Options

Athlete's complete rectus femoris rupture must be carefully considered in terms of treatment. Surgical treatment of proximal rectus femoris avulsions (Fig. 2) is recommended for patients with moderate to high functional demands or patients with chronic pain and poor results after conservative

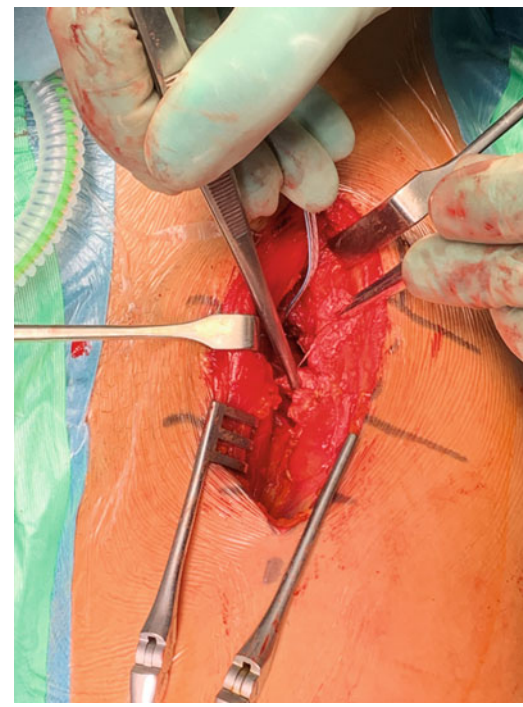

Fig. 2 An intraoperative photo of a proximal rectus femoris rupture

treatment. There is only limited amount of studies published on the results of different treatments [39]. Randomized controlled trials comparing operative and conservative treatment are totally lacking. However, in addition to complete proximal ruptures with clear retraction (>15–20 mm), in cases of recurrent tendon injuries and complete mid-substance ruptures, the operative treatment should be considered [27, 31, 44]. Additionally, central tendon ruptures of the rectus femoris may require surgical treatment, especially in reinjuries and chronic cases [44].

Complete ruptures of the quadriceps tendon (Fig. 3) should be treated surgically in all cases [45, 46].

Primary surgical repair of the ruptured tendon and excision of the proximal tendon remnant with muscular suture tenodesis are the surgical techniques that has been found to lead to good functional results compared to nonoperative approach [47].

Fact Box 4

Athlete's complete rectus femoris rupture must be carefully considered in terms of treatment. Surgical treatment of proximal rectus femoris avulsions is recommended for patients with moderate to high functional demands or patients with chronic pain and poor results after conservative treatment.

Fig. 3 A complete rupture of the quadriceps tendon

Postoperative Rehabilitation and Return to Sport Discharge Criteria

The postoperative rehabilitation protocols can slightly vary depending on the specific injury type and surgical technique used. For example, after reattachment of the ruptured proximal rectus femoris tendon, the patients are advised to use crutches for 1–2 weeks. No braces or orthoses are recommended to use. Weight-bearing is allowed gradually as soon as it is pain-free. At rest, the operated side hip is advised to be kept in a slight flexion to avoid stretching on the rectus femoris. This can be performed by placing the leg on the pillow, for example. The next allowed exercise types are muscle activations and pool training, as well as slow and calm stretching exercise of the hip joint to all directions. Four weeks after injury, easy cycling and aqua weight training can be started. Eccentric exercises are allowed 6 weeks after surgery and jogging and running 8 weeks after surgery. Physical therapy is an important factor throughout the whole rehabilitation process. The special attention in physical therapy is paid to balance, coordination, and strength. Sport-specific activities, such as ball training and kicking for soccer players and sprinting and jumping for track athletes, can be started between two and three months after surgery. The training load should be increased step by step, and careful monitoring of the physical factors is essential. In 3–6 months after the surgery, clinical strength measurements should be performed by the medical team. If the athlete can perform with full intensity without symptoms and the hip flexion strength is equal to the contralateral side, permission to return to sport can be given.

Outcomes

As mentioned before, there are only limited amount of evidence in the literature on outcomes after quadriceps muscle injuries. There are good results and return to sport rates after the surgical treatment and rehabilitation on complete proximal rectus femoris tear [27, 47]. After surgical treatment, athletes return to sport in 3–4 months in complete

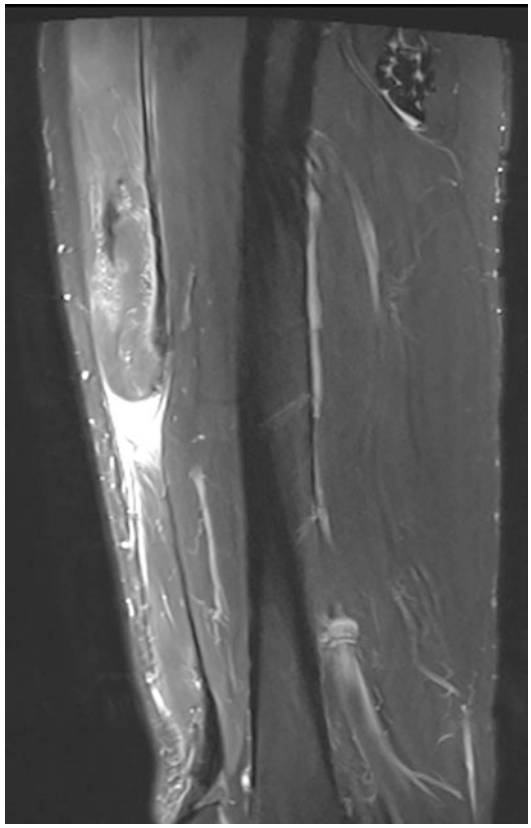

Fig. 4 A complete rectus femoris mid-substance rupture in MRI

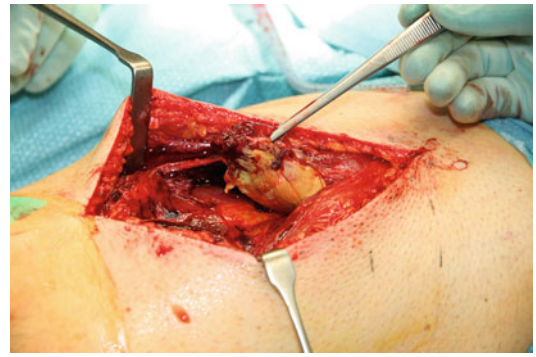

Fig. 5 An intraoperative photo of the rectus femoris mid-substance rupture

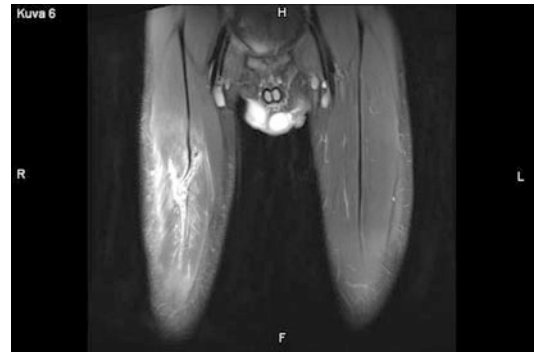

Fig. 6 An MRI of the rectus femoris central tendon rupture

proximal rectus femoris ruptures and in 4–5 months in complete rectus femoris mid-substance ruptures (Figs. 4 and 5) [27, 31, 47]. After surgical treatment of recurrent and chronic ruptures of the central tendon (Fig. 6), return to sport is typically possible in 3 months after surgery [44].

Complete ruptures of the quadriceps tendon invariably require surgical treatment, and return to sport is usually possible in 6–9 months after surgery [45, 46]. However, for some athletes, these injuries are career-ending [48].

Times to return to full training after rectus femoris injury have been researched also in elite track and field athletes [49]. It has been found that it takes the average of 20.4 days for conservatively managed rectus femoris injury and 129.8 days for surgically treated cases to return to full training. Naturally, these injury types are classified as different ones, and conservatively treated injuries are not at the same severity class as surgically treated cases. Additionally, intratendinous injuries take more time to heal, similarly to hamstring injuries.

Conclusion

Quadriceps muscle injuries are quite common in elite and recreational athletes, especially in sports involving kicking and sprinting. Most of the injuries are mild and can be treated conservatively. However, some more severe injuries may require surgical treatment to optimal recovery. The correct diagnosis in the initial phase is crucial in successful treatment.

The most typical indirect injury mechanisms are kicking the ball, sprinting with maximal speed, or jumping. Injuries to the proximal free

tendon of rectus femoris muscle are most common after these injury mechanisms. In contact sports, direct contusion to quadriceps muscle is also typical injury mechanism. On physical examination, the patient typically feel palpable pain in anterior thigh, which is combined with weakened knee extension or hip flexion. Additionally, hematoma and swelling may be present.

MRI is a cornerstone in quadriceps muscle injury diagnostics as it reveals the location, extent, and severity of the injury very well. The treatment decision is based on patient history, clinical examination findings, and imaging. Especially in high-level athletes, total tendon ruptures and clear injuries on the tendinous area often require surgical treatment.

Conservative treatment includes rest, ice, compression, and pain-free exercise in acute phase. The rehabilitation process proceeds progressively. If the conservative treatment fails or remarkable anatomic disorder can be found, surgery can be considered also in chronic phase.

In addition to muscle and tendon injuries, some other pathologies and causes of anterior thigh pain can be differential diagnostic options. However, careful examination combined with patient history and MR imaging likely lead to correct diagnosis.

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