Proximal Hamstring Avulsion

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Abstract

Hamstring injuries are common in professional and recreational athletes, and they account for one third of all muscle-tendon injuries. However, hamstring injuries occur also in everyday life and slipping is a typical injury mechanism among general people. Patient history, clinical examination, and magnetic resonance imaging are the most important things in terms of

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diagnostics. Most of the hamstring injuries are mild strains and heal well by conservative treatment. There are also clear indications for surgical treatment, such as complete proximal hamstring avulsion with impaired function and poor strength of the hamstring muscles. In high-level athletes, more aggressive recommendations for surgical treatment are seen.

Keywords

Hamstring · Proximal avulsion · Muscle · Tendon · Biceps femoris · Semitendinosus · Semimembranosus

Epidemiology

Hamstring injuries are common in athletes participating sports that involve running, acceleration, jumping, and rapid changes of direction [1–3]. Typical sports or activities predisposing to hamstring injuries are football, track and field, dancing, running, and waterskiing. In football, they are the most common injury type causing time lost from sports. Hamstring injuries account for 12% of all injuries and 37% of muscle—tendon injuries in footballers [4]. Most injuries involve the proximal part of the biceps femoris (BF) muscle. Hamstring injuries are prevalent not only in athletic people but also among the general population, for example, due to slipping. Most of the injuries are mild strains, but also severe high energy avulsions occur. Most of the complete proximal hamstring avulsions occur in middle-aged people due to exercise activities or slipping [5, 6].

Fact box 1: "Typical sports or activities predisposing to hamstring injuries are football, track and field, dancing, running, and waterskiing"

Specific Anatomy

The hamstring muscle group is formed by three muscles: BF, semimembranosus (SM), and semitendinosus (ST) [7]. BF has a long head (BFlh) and a short head (BFsh). These muscles attach from their proximal part to the ischial tuberosity except for the BFlh, which originates at the linea aspera of the femur. SM has its origin on the superolateral aspect of the ischial tuberosity underneath the proximal part of BF. The ST has its origin on the inferomedial part of the ischial tuberosity, forming a common tendon with the BFlh. The common tendon extends approximately 10 cm distally, until the ST and BFlh separate into the two muscles. ST can also have an own insertion area due to anatomical variations [8]. All the hamstring muscles have an intramuscular tendon extending distally the whole length of the muscle belly [9]. Distally, the hamstring muscles attach to the knee: BF to the proximal head of the fibula and SM and ST mainly to the posterior medial condyle of the tibia. The illustration of the anatomy of hamstring muscles is presented in Fig. 1.

Anatomically, the sciatic nerve and the hamstrings have very close relationship, as there is only approximately 1.2 cm distance between the nerve and the hamstring origin at the ischial tuberosity [10]. The close proximity of the sciatic nerve can lead to neurological symptoms in acute hamstring injuries. Additionally, neurological symptoms related to the sciatic nerve are often seen in chronic hamstring problems, such as proximal hamstring tendinopathy [11]. When hamstring injuries are treated surgically, the sciatic nerve must be identified and protected intraoperatively. All three hamstring muscles cross both the hip and knee joints, as they attach proximally to the ischial tuberosity and distally to fibula and tibia. The nature of two-joint muscle tendon unit makes hamstring vulnerable to injury, as they work concentrically in knee flexion and hip extension, and eccentrically in the opposite functions.

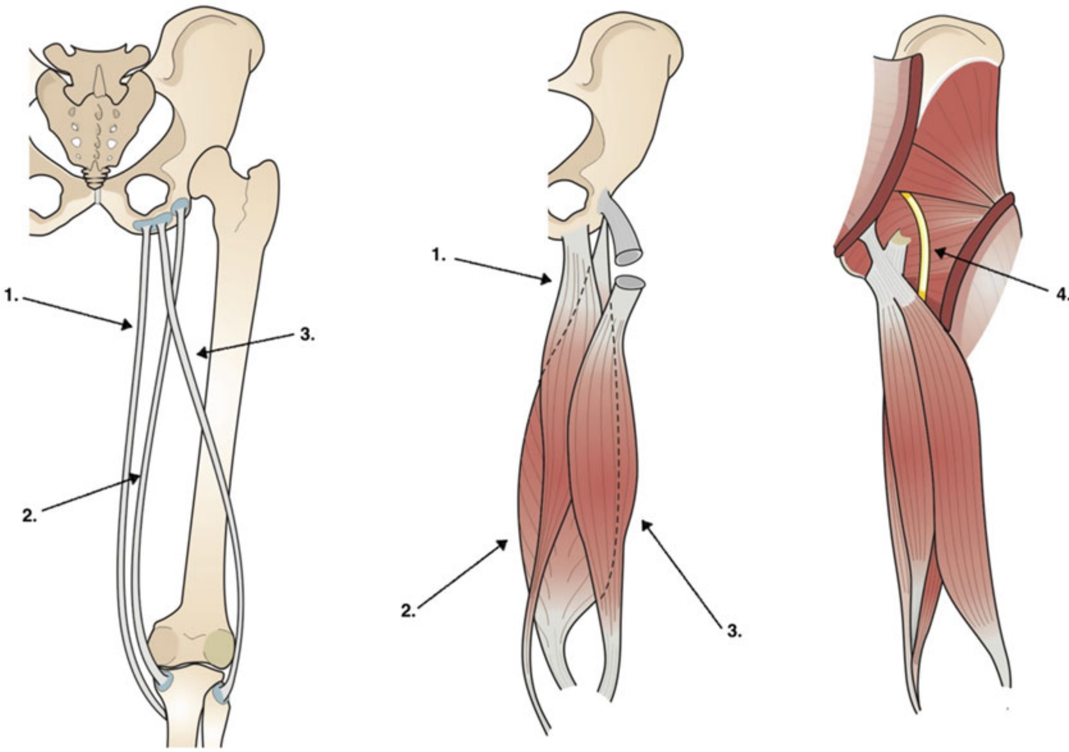

Fig. 1 The anatomy of hamstring muscles: (1) the semitendinosus, (2) the semimembranosus, (3) the biceps femoris, and (4) the sciatic nerve. (Graphics by Sole Lätti)

Biomechanics

The main functions of the hamstring muscles are hip extension and knee flexion. The hamstring muscles work eccentrically in knee extension to prevent excessive extension of the knee. BFlh, SM, and ST are innervated by the tibial branch of the sciatic nerve, and BFsh gets its innervation from the common perineal branch [9].

The gait cycle includes stance and swing phases, and the former is further divided into foot strike, mid stance, and takeoff [12]. The swing phase is divided into follow-through, forward swing, and foot descent. It has been found that the BF and the SM are actively contracting at the beginning of the foot strike, providing stability to the knee. After that, the ST starts to activate and assists the BF and the SM. Just before the takeoff, all three hamstring muscles are highly activated, which continues through the knee flexion. During the follow-through phase, the hamstring muscles are less active until the forward swing. During that, the SM starts to increase its activity and works eccentrically, whereas the BF is inactive during this phase. In the end of the swing phase, the hamstring muscles are highly active and work eccentrically to stabilize the knee, and just before the foot strike, the hamstring muscles change rapidly to concentric activity to prepare weight loading [13]. This is speculated to be the most likely moment of hamstring injury occurred during high-speed running [14].

Etiology

Risk Factors

A great number of risk factors for hamstring injuries have been found in previous studies, and often, injuries are caused by several reasons. Of the individual risk factors, the most important are previous hamstring injury and higher age [15]. Athletes with previous hamstring injuries have 2.7 times higher likelihood of sustaining a hamstring injury than those without the history, and the risk is even five times higher if the previous hamstring injury occurred during the same season [15]. The tightness, poor mobility and impaired strength of the hamstring muscles, increased quadriceps peak torque, athlete fatigue, and lack of an appropriate warm-up before sports performance are also essential risk factors [13]. The risk of hamstring injury can be modulated by other factors such as the physical characteristics of the athlete, exposure to load, and mechanical function when performing [15].

Injury Mechanism

Running at high speed is a typical injury mechanism for hamstring injuries, and it has been suggested that the late swing phase is the most likely injury moment during running [14, 16, 17]. In the late part of the swing phase, the hamstring muscles are maximally activated and approaching their maximum length while working eccentrically before the rapid change to concentric function.

The other of the two most common injury mechanisms is stretching as the hamstring muscles overstretch due to excessive hip flexion with the ipsilateral knee extended. This injury mechanism is typical for dancers performing sagittal split, football players reaching the ball, or in everyday life after uncontrollable slipping [18–20]. The most severe proximal hamstring avulsions usually occur when slipping into a sagittal split position [21]. In this case, sudden and forceful flexion of the hip and simultaneous stretching of the ipsilateral knee cause the maximum stretching of the hamstring muscles leading to avulsion of the proximal tendons from the ischial tuberosity.

> **Fact box 2: "The two most typical hamstring injury mechanisms are sprinting and stretching. The most severe proximal hamstring avulsions usually occur when slipping into a sagittal split position"**

Diagnosis

Classifications

Hamstring injuries are typically classified due to their location, severity, and muscles involved. Typically hamstring injuries are located at the myotendinous junctions (MTJ). However, the tendons of hamstring muscles extend far into the muscle bellies and form elongated MTJs and central tendons. Therefore, hamstring injuries are often categorized into proximal, central, and distal 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. Traditionally, proximal hamstring avulsion has been classified as a typical example of grade III injury. The most common classification model used in proximal hamstring avulsions is the one established by Wood et al. [22], which is based on the anatomical location, the degree of avulsion (incomplete or complete), the degree of muscle retractions, and the possible presence of sciatic nerve tethering. However, nowadays, more specific injury classification has been proposed in hamstring injuries, especially for athletes [23]. When the injury has been accurately diagnosed, the involved muscle(s) should be individualized and classified accordingly. For example, if a high-level athlete suffers severe, complete proximal BF tendon rupture, it should be classified as grade III BF rupture instead of partial proximal hamstring tear, which may often result to underestimation of the severity of the injury and thus poor functional performance, if the wrong treatment method is chosen.

In addition, hamstring injuries are often classified according to the time passed from the initial injury. There is no firm consensus about the definition of acuity or chronicity, but often 3 weeks is commonly used as a timepoint between acute and chronic injury.

Physical Examination

After the proximal hamstring avulsion, the function of hamstring muscles is often significantly impaired, especially against resisted function. The proximal hamstring area can be painful, and a palpable gap may be felt due to retraction of the hamstring muscles.

After a few days, hip extension and knee flexion without resistance begin to succeed due to the relief of pain and recovery of the gluteus muscle and the short head of biceps femoris. However, movements are clearly powerless if the patient is asked to perform knee flexion or hip extension against resistance.

If there is a rupture also in so-called common fascia in addition to the hamstring tendon or muscle, hematoma typically appears on the skin with a delay of a few days (Fig. 2). However, the patient may have a complete hamstring tear of the proximal part without visible hematoma [11].

The proximal hamstring avulsion often causes pain while sitting, in addition to weakness and pain during movements requiring hamstring contraction. Additionally, typical symptoms of a complete avulsion are muscle cramps in the posterior thigh, impaired coordination of the leg, and lack of control in movement, for example, when walking downstairs. Patients may also describe radiation symptoms caused by irritation of the sciatic nerve. They are more common in chronic ruptures than in acute ones [24].

In addition to proximal avulsions, a hamstring injury can also appear in the lower part of the thigh. The most severe pain area is typically close to the popliteus. Knee flexion against resistance is weak and causes pain. The rupture of the distal part of the hamstring muscle is often palpable. In chronic stage, it can be clearly felt as a pit

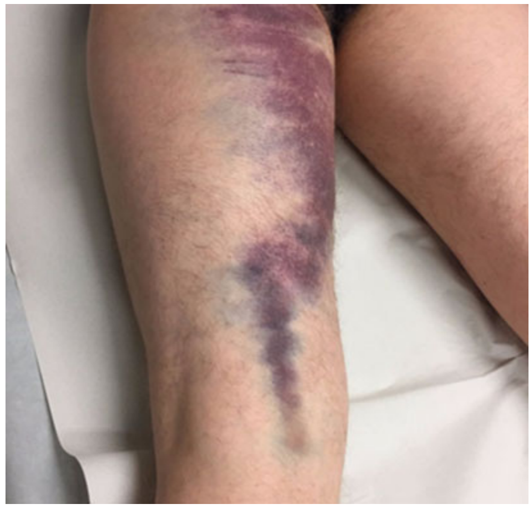

Fig. 2 A complete proximal hamstring avulsion with clear hematoma

on the skin, especially when there is resistance to flexion of the knee [25].

In clinical examination, the patient may use their gastrocnemius to compensate the weakened hamstring function, when asked to flex their knee while lying prone. In acute phase, the proximal hamstring area is often so painful that the sensitivity and specificity of clinical examination are poor.

Fact box 3: "The proximal hamstring area can be painful, and a palpable gap may be felt due to retraction of the hamstring muscles"

Imaging

Imaging plays a significant role in diagnostics of hamstring injuries and in assessing the degree of severity. Imaging finding helps the decision of treatment line and evaluation of the length of rehabilitation time [26]. Imaging can also be utilized in terms of differential diagnostics.

Magnetic resonance imaging (MRI) is the most reliable method in proximal hamstring injuries. Therefore, it is considered the gold standard test for hamstring injuries. MRI is often able to accurately estimate, for example, the amount of retraction of a ruptured tendon from the ischial tuberosity [27]. It can also differentiate whether the avulsion is partial or complete and acute or chronic and identify the tendons involve (Fig. 3) [28]. If MRI has been performed immediately after the injury, the injured area may be partially invisible due to the hematoma. In this case, the MRI examination is advised to repeat after 1–2 weeks [29].

Ultrasound (US) is a noninvasive, cost-efficient, and readily accessible test that can also be used in diagnostics of hamstring soft tissue injuries. However, the method is considered not to be precise or detailed enough to plan the surgical treatment, for example. Therefore, MRI is a first choice in diagnosing hamstring injuries. US can be used mainly in distal ruptures where muscle and tendon structures are located more superficially [28].

Other Diagnostic Criteria

Hamstring injury mechanisms and their relation to injury types have been investigated in the previous literature [16–20, 30]. Two main actions causing hamstring injuries are running at a very high speed (sprinting) and a sudden hyper flexion of the hip with the simultaneous knee extension (stretching).

Hamstring injuries are most commonly located in the proximal BF [20]. Sprinting is the most typical injury mechanism causing proximal BF injuries [17]. It has been suggested that sprint-type hamstring injuries are most likely to happen due to rapid change from concentric function to eccentric contractions in the late swing phase of the running gait cycle [16].

Stretching-type injuries typically lead to proximal SM injuries [18]. The most severe avulsions typically occur during forceful and uncontrolled hip flexion with the simultaneous knee extension on the same side [22, 31].

Hamstring injuries can be complex and occur in various situations. In addition to clear sprint-type or stretch-type injuries, combinations of different injury mechanisms are also possible. For example, the most common injury situation in Australian football is when the player tries to pick up a ball from the ground while running at full speed, which included factors from both sprinting-type and stretching-type injury mechanisms. With combinational injury mechanisms, it may be more difficult to predict the injury type, and some studies have reported BF being the most commonly injured muscle also in stretching-type injuries [20].

Prevention

The hamstring injury prevention is crucial in management of athletes' injuries. Hamstring injuries are often troublesome and long-lasting for athletes and impose considerable costs on clubs in elite sports.

The essential thing is to address risk factors. Eccentric hamstring strength exercises reduce risk of injury and improve athletes' performance

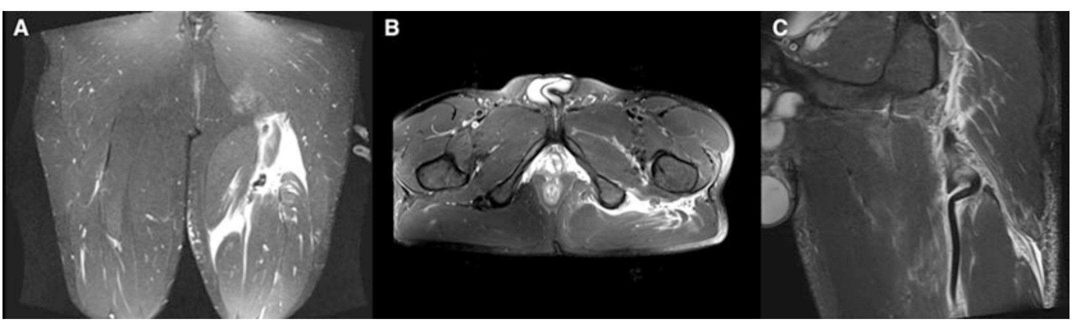

Fig. 3 Coronal (**a**), axial (**b**), and sagittal (**c**) views of complete proximal hamstring avulsion in MRI

[17, 30, 32]. Mobility exercises are also effective in injury prevention [33].

Probably, the most effective injury prevention programs include combinational exercises, which focus on activating warm-up and post-exercise cool down, mobility and strength exercises, coordination, reaction time, and endurance. Exercises that simulate game situations (drills, interval, and agility exercises) are also effective [34, 35].

Conservative Treatment

Most hamstring ruptures can be treated conservatively, following common principles of acute muscle—tendon injury and rehabilitation. The goal of treatment is simple: to allow the return to sports as well as everyday life on pre-injury level and minimize the risk of reinjury. Rehabilitation is often carried out in cooperation with a physiotherapist.

Rehabilitation is divided into three stages. In the beginning, the focus is on the treatment of acute injury and the prevention of further damage. Treatment of edema, light compression, avoidance of stretching, light movement (crutches may be needed), and activation of supporting/compensatory muscles aim at rapid recovery in the early stages, as well as to minimize the size of scar tissue and the size of injured area.

Exercises are performed in a lightened, modified way, without resistance and limited motions avoiding stretching. Before progressing to the next stage, the athlete must be able to walk or jog lightly without pain. In addition, he must be able to make isometric hamstring exercises against resistance in a prone position with a knee in 90° flexion, the resistance being about 50–70% of submaximal.

In the second stage, the power and range of motion are gradually increased until normal mobility have been reached. Eccentric muscle exercises are also started gradually and with light exercises. More demanding exercises should be started in moderation and only with light resistance if the injured leg still feels weak. The amount and intensity of pelvic stabilizing exercises is increased.

The third stage of rehabilitation (sport-specific) can be entered when the maximal force of isometric hamstring contraction in a single repetition exercise is achieved in prone position with the knee in 90° flexion and when the athlete can jog forward and backward at a speed of 50% of pre-injury level.

In the third phase, the attention is paid to actual eccentric strength exercises and more demanding coordination training. The aim is to perform sport-specific exercises and movements. Combination exercises include progressive body control, sport-specific sprints, and dynamic agility exercises.

Return to sports is possible when the exercises can be performed without pain, there is no soreness on the area of injury in palpation, and pre-injury level strength levels and range of motion have been achieved pain-free [36, 37].

The progression of rehabilitation is affected by the restoration of the function of the damaged muscle. The speed of progression is often individual for an athlete. It is particularly affected by the anatomical structure of damaged tissue and the severity of the injury. In rehabilitation, the requirements of the patient's functional capacity must be taken into account individually. When the progression of rehabilitation is well planned, the prevention of recurrent injuries is more effective [17, 30, 34].

Surgical Options

In hamstring injuries, the main indication for surgical treatment is a complete proximal hamstring avulsion, accompanied by a clear tendon retraction and weak hamstring function. In these cases, also nonathletes clearly benefit from surgical treatment, especially in acute phase (<3 weeks) [6, 11, 22, 24, 38].

A proximal hamstring avulsion (Fig. 4) can be career-ending for an athlete, especially if the choice of treatment turns out to be wrong [11]. For the high-level athletes, absolute indications for surgical treatment most often include clear avulsions of proximal tendons (Fig. 5) or their combination injuries [11, 23, 39, 40].

Fig. 4 An intraoperative photo of a complete proximal hamstring avulsion

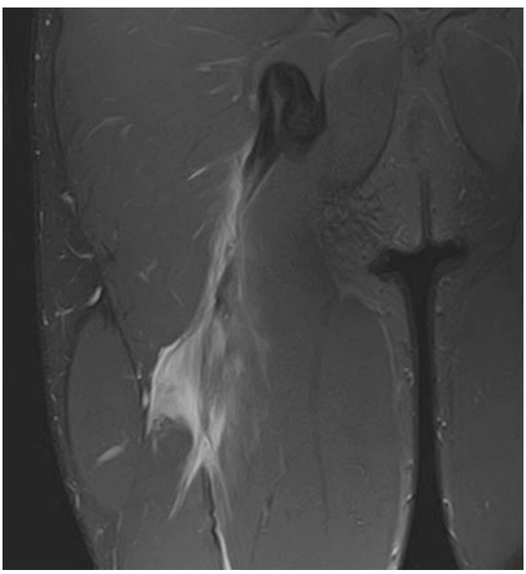

Fig. 5 An MRI of a proximal biceps femoris rupture

In addition, the complete ruptures of the distal hamstring tendon (BF, SM, or ST) should be treated surgically to obtain good results [25, 41]. A teenage athlete may suffer an avulsion fracture of the ischial tuberosity. If the avulsion fragment has clearly displaced (10–15 mm), the surgical treatment is often needed [42].

Tendinous injuries to the free tendon or central tendon of hamstring muscles are challenging to treat and often require a longer rehabilitation period than muscular injuries. Surgical treatment should be considered, if the central tendon is completely ruptured with clear retraction or if the recurrent central tendon injury occurs after conservative treatment [29].

Despite the appropriate rehabilitation, some partial ruptures of the proximal hamstring are not healed by conservative treatment. In this case, the athlete's level of performance can usually be restored with surgical treatment and good rehabilitation, and the prognosis for the continuation of a sports career after surgical treatment is often good [43, 44].

In chronic and retracted proximal hamstring ruptures, anatomic apposition of the muscles and tendons cannot always be achieved. In those cases, graft augmentation can be used to connect the retracted hamstrings to ischial tuberosity. It seems that late reconstruction of complete proximal hamstring avulsion with fascia lata autograft augmentation results in enhancement of muscle strength, better function of the hamstrings, and improved leg control [45]. Also, symptoms derived from retracted hamstrings causing stretching to the sciatic nerve could be alleviated.

Fact box 4: "In hamstring injuries, the main indication for surgical treatment is a complete proximal hamstring avulsion, accompanied by a clear tendon retraction and weak hamstring function"

Postoperative Rehabilitation and Return to Sport Discharge Criteria

After surgical treatment of a proximal hamstring avulsions, easy muscle activation (gluteus, calves, adductors, and quadriceps) can be started soon. No casts or orthoses are advised to be used. Sutures are typically removed after 10–12 days.

The crutches are used for 2–3 weeks, during of which partial and reduced weight-bearing is allowed. The return to full weight-bearing is reached gradually and carefully. Sitting should be avoided for the first 2–3 weeks after surgery to prevent excessive pressure and stretching for the operated area. After 4 weeks, light pool training can be started, including muscle activations in the pool and aqua walking/running. For the first 4 weeks, all kind of stretching of the hamstring muscles should be avoided. After 6 weeks, cycling and elliptical trainer are often allowed. Six to eight weeks after surgery, functional mobility exercises can be started. Running and more active muscle training can be started in 3–4 months after the operation if the rehabilitation has progressed well and the patient is pain-free. After that, the final stage of rehabilitation is quite like the third stage of conservative treatment described earlier. Progress to sport-specific exercises is performed gradually and according to the patient's symptoms. It is important to progress "step by step" and respect the biological time needed for muscle-tendon injury healing process.

Similarly to the conservative treatment, return to sports can be considered when the training is pain-free, the palpation pain or soreness on the injury area has vanished, and normal strength levels and range of motion have been achieved without pain [5, 37].

Outcomes

The results of surgical treatment in proximal hamstring avulsions are good, both in complete and partial avulsions [24, 46]. Operatively treated patients have better satisfaction, strength testing results, endurance levels, and return to sport rates than nonoperatively treated patients [6, 46]. It has been found that operative repair in acute phase leads to better results with higher satisfaction and better functional outcomes, when compared to chronic repair. Additionally, the risk of complications increases significantly, if the surgery is performed later. The surgical treatment of complete avulsion leads to better outcomes when compared to partial repairs, which may be due to the chronicity as partial avulsions are more often treated after failed conservative treatment [24].

Ninety-two percent of patients are satisfied with the outcome after the surgical treatment of complete avulsion and 87% with partial avulsions. Most of the patients treated surgically return to sport on same level after proximal hamstring avulsion [24].

Conclusion

Muscle and tendon injuries are very common in sports requiring eccentric contractions and high speeds, and 30–40% of all sports injuries are muscle-tendon injuries. Of these injuries, hamstring injuries are the most common, as they account for 30–40% of all muscle-tendon injuries. In addition to high-level athletes, hamstring injuries can occur in everyday life and among ordinary people. Typical injury mechanisms of hamstring injuries are stretching (excessive hip flexion with the ipsilateral knee in extension), sprinting (maximal-speed running), and combination of these two mechanisms.

The severity of hamstring injury varies from mild strains to complete avulsions with clear tendon retraction. Most of the hamstring injuries heal well by conservative treatment. However, there are also certain indications for surgical treatment. Surgical treatment is recommended in complete avulsions for all patients, in retracted single- or two tendon avulsions for athletes, and if the conservative treatment has failed. In proximal hamstring avulsions, the early surgical treatment has been found to lead to good results, high return to sport rates, and low complication rates.

From the clinical point of view, patient history, injury mechanism, clinical examination, and MR imaging are the most important things when managing hamstring injuries. Hamstring injuries may be challenging and long-lasting trouble. Therefore, the most crucial thing is to choose correct treatment in early phase to find the patients who are expected to benefit from acute repair. The rehabilitation must be performed in close collaboration with physiotherapists, and the progress must be gradual.

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