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Abstract

Hamstring muscle injury is common among athletes and can range in severity from mild strains to complete ruptures of the hamstring muscle complex. Injury to the hamstring muscles is commonly sustained during eccentric contraction of the muscle while running or stretching carried out to extreme joint positions. Diagnosis is based on patient history, physical examination, and imaging by means of ultrasound and MRI. The best way to treat a hamstring muscle injury depends on the extent, precise location, and function the muscle is required to regain. This chapter will address relevant anatomy, function, epidemiology, symptoms and signs, imaging, treatment, and prevention.

3.1 Introduction

The term “hamstrings” is derived from the butcher’s practice of hanging a pig’s ham by its distal tendons or “strings.”

Hamstring muscle strains are common in many kinds of sports and often account for extensive absence from training and competition. Injuries range in severity from mild strains to complete ruptures of the hamstring muscle complex. This chapter will address relevant anatomy, function, epidemiology, symptoms and signs, imaging, treatment, and prevention.

3.2 Definition of the Injury

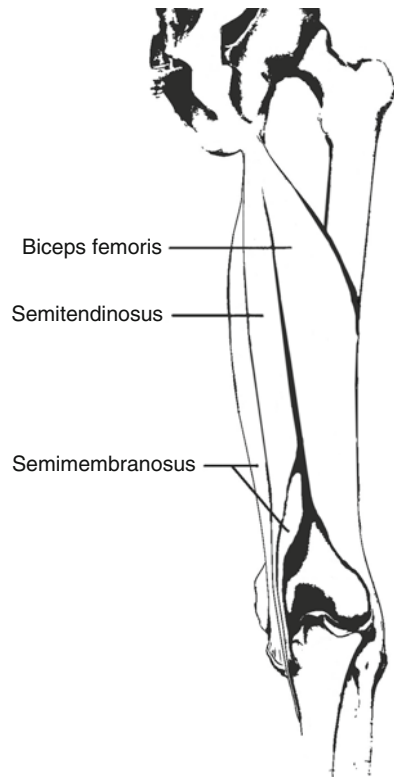
3.2.1 Anatomy

The hamstrings, or ischiocrural muscles, consist of the three muscles in the posterior thigh region that span both the hip and knee joints: semitendinosus, semimembranosus, and biceps femoris (long head) (Fig. 3.1) [18]. Originating from the ischial tuberosity, the semitendinosus and (long head of the) biceps femoris have a common proximal tendon. Anterior to that, the semimembranosus muscle originates on the ischial tuberosity as well. The semitendinosus and semimembranosus extend approximately 44.3 and 38.7 cm [25], respectively. They are attached to the medial condyle of the tibia via the superficial pes anserinus in case of the semitendinosus and to the posteromedial aspect of the medial condyle of the tibia in case of the semimembranosus.

The semitendinosus separates from its common origin with the biceps femoris at approximately 9 cm [25] from the ischial tuberosity at a greater pennation angle than the biceps femoris. A recent study suggested that this angle could make the proximal part of the semitendinosus susceptible to injury [5]. The semitendinosus muscle is divided into two separate parts by a tendinous section, known as the raphe, effectively making the semitendinosus a “digastric” muscle [15].

The long head of the biceps femoris muscle, after separating from its common origin with the semitendinosus muscle, is joined by its short head originating just medial to the linea aspera of the distal femur to traverse the knee joint at the lateral side and attach in a common tendon to the fibular head. Just proximal to the

Fig. 3.1 Schematic view of hamstring muscle complex



fibular head, this common tendon is divided into two components, namely, a direct arm and an anterior arm, and several fascial components. The direct arm is inserted on the posterolateral edge of the fibular head, whereas the anterior arm is inserted on the lateral edge, its lateral side terminating as an aponeurosis covering the anterior compartment of the leg. Other insertions of the short head include attachments to the posterolateral joint capsule and to the iliotibial tract [23]. The long and short head of the biceps femoris extend approximately 42.0 and 29.8 cm, respectively [25].

The tibial part of the ischial nerve supplies nerves of the semitendinosus, semimembranosus, and long head of the biceps femoris, whereas the short head of the biceps is innervated by the peroneal part of the ischial nerve. This difference in innervation is often thought to contribute to difficulty in coordination that might lead to injury within the biceps femoris muscle [15].

3.2.2 Function

The hamstring muscles are extensors of the hip and flexors of the knee, absorbing kinetic energy and protecting the hip and knee joints during the gait cycle by limiting knee extension just before and during heel strike. During the gait cycle, there is interplay between the hamstrings and the quadriceps in an antagonizing way [18].

3.2.3 Injury Mechanism

Hamstring muscle injury occurs during eccentric contraction rather than concentric contraction. Eccentric contractions take place in a state of muscle stretching, in which the contracting muscle fibers put even more tension on the stretched muscle. Because the prime function of the hamstring muscle complex is to absorb kinetic energy by eccentric contraction, it is vulnerable to strain injury, especially the region adjacent to the MTJ (musculotendinous junction) [15, 18].

Recent studies pointed out that different sports lead to lesions in different regions of the hamstrings muscle complex through different injury mechanisms. Two distinct types of injuries are known: the high-speed running type [3] and the stretching type [4]. The high-speed running type, incurred during sports as football or athletics, is strongly associated with injuries in the long head of the biceps femoris muscle [3]. Injuries of the stretching type occur during stretching exercises carried out to an extreme joint position (hip flexion and knee extension), as is the case with dancing or kicking during rugby. They are often complex, but mainly involve the semimembranosus muscle and its proximal free tendon close to the ischial tuberosity [4]. These types of injury have different prognoses, which is illustrated by the time that is needed to recover to pre-injury level, which is longer for the stretching type [2].

Apart from the injury mechanism, the precise location of the injury within each muscle also corresponds with different prognoses. Hamstring muscle strains, generally occurring at the proximal sections of a muscle, prove to be more problematic as they are located closer to their origin at the ischial tuberosity [1]. Involvement of the free proximal tendon is also associated with longer time to return to the pre-injury level [3].

3.3 Epidemiology

Incidence rates of hamstring muscle injury vary widely, depending on the type of competition an athlete competes in. In soccer, the incidence rate is 52/1,000 players per year [9]. In rugby, incidence rate has been reported as injuries per 1000 player training or match hours. The incidence of hamstring muscle injury is 0.27/1,000 player training hours and 5.6/1,000 player match hours [6]. Similarly, In the National Football League (NFL), also known as American Football, incidence is calculated as injuries per athlete exposure (AE), with every training and match counting as an exposure. The total injury rate in the NFL for hamstring muscle injuries is 0.77/1,000 AE, 0.47/1,000 AE during practice, and 2.70/1,000 AE during matches [11]. Overall, the biceps femoris muscle is most often injured, followed by the semitendinosus muscle and the semimembranosus muscle [15, 16].

3.4 Symptoms and Signs

While people with a mild hamstring lesion seldom seek medical attention, athletes incurring a moderate or severe injury will typically do so. The patient's history will relate a sudden onset of pain in the posterior thigh region, most likely during

sprinting or extreme stretch. Hamstring muscle injuries of the high-speed running type occur during sprinting when speed is (close to) maximal, causing the athlete to stop running at once [3]. Injuries of the stretching type are often experienced as acute pain close to the ischial tuberosity, accompanied by an audible “pop” [4]. Predisposing factors include inadequate warm-up, muscle fatigue, poor muscle strength, poor lumbopelvic strength and stability, older age, muscle imbalance between quadriceps and hamstrings, muscle imbalance between left and right hamstrings, previous hamstring muscle injury, and L5 nerve root entrapment [18].

3.4.1 Physical Examination

Although the value of a physical examination in (suspected) hamstring muscle strains remains controversial [1], expert opinion and a review of the available literature seem to agree on several issues. The initial assessment should take place within 2 days post-injury to ensure a reliable medical history and possibility of a quick intervention when necessary, yet allow possible signs of swelling and hematoma to develop [14].

Inspection should mainly focus on posture and gait examination, focal swelling, and hematoma. Both inspection and palpation of the injury site can help identify the muscle involved as well as determine the proximity of the injury. For instance, in case of a true hamstring avulsion, extensive bruises can be seen on the posterior thigh and a defect in the tendon may be felt if there has been sufficient retraction [8].

During palpation, athletes with hamstring injuries of the high-speed running type report their highest pain in the lateral part of the posterior thigh, about 11–12 cm (± 7 , 4–24) distal to the ischial tuberosity. With this type of injury, there is a significant correlation between the location of the point of highest pain and the length of the convalescent period. The more proximal the point of highest pain, the longer the convalescent period. Length of the painful area however does not correlate with the duration of the convalescent period [3].

Athletes with the stretching type hamstring injury report their highest pain in the proximal posterior thigh, 2 cm (± 1 , 0–5) distal to the ischial tuberosity. The convalescent period of the stretching type injury does not correlate significantly with the location of the highest pain [4].

Despite possible inaccuracies due to pain, range of motion (ROM) testing should reveal decreased flexibility in the affected leg. The best way to establish a deficit in the posterior thigh region is by using passive or active straight leg raise and passive or active knee extension tests. The “sit-and-reach” test should be omitted from standard ROM testing due to confounding factors such as spinal mobility (i.e., lumbar flexion), leg length, scapular abduction, and stretch on the peripheral nerves by dorsiflexion of the ankle joint.

With the patient lying supine, the strength of the hamstring muscles can be examined by comparing knee flexion and hip extension between both legs. In this way, a possible decrease in strength of the affected leg can be determined, although it is good to realize that this could also be caused by pain instead of fiber disruption [2]. The use of the “hamstring drag” test remains controversial and needs further validation [14].

Table 3.1 Clinical classification for hamstring muscle injury [1]

Classification	Degree	Symptoms	Architectural damage
Mild	First	Minor discomfort, minor swelling, no/minimal loss of strength, and restriction of movement	Microscopic muscle fiber disruption
Moderate	Second	Marked discomfort, diminished ability to contract	Macroscopic muscle fiber disruption
Severe	Third	Distinct pain, total loss of muscle function	Complete rupture of muscle-tendon unit, possibly with avulsion fracture

3.4.2 Clinical Classification

As with other muscle injuries, hamstring strains are conventionally classified according to the impairment they cause [1], which generally is a direct consequence of the extent of damage to the muscle-tendon unit. In this way, hamstring strains are defined as mild (first degree), moderate (second degree), or severe (third degree) [1] (Table 3.1). This classification system, however, is quite indistinct and does not take into account that the precise location of a hamstring injury can influence the duration of symptoms and time to return to full activity to a large extent. A minor tear in the proximal biceps femoris, for example, can have greater consequences than a larger injury located more distally [1]. Preferably therefore, a future clinical classification system will take these factors into account.

3.5 Imaging

Imaging can provide detailed information on the nature and extent of hamstring muscle injuries [15]. Magnetic resonance imaging (MRI) and ultrasound (US) are the modalities of choice [14, 15]. Nevertheless, MRI is preferred over US because it is more sensitive in identifying minimal injury [14]. Moreover, it is more difficult to use US to accurately assess an injury that is located deeper within the muscle, and its interpretation is subject to greater interobserver variability [13, 15]. Edema and hemorrhage along disrupted muscle fibers show as a hyperintensity in a characteristic feather-shaped appearance on STIR (short tau inversion recovery) and T2-weighted MR images [15]. Because the amount of edema reaches its maximum after 24 h and decreases after 48 h, MRI is preferably performed 1–2 days post trauma [10, 13, 14]. To grade hamstring muscle injury based on radiological findings, Peetrons [19] classification modified for MRI [10] is reproduced below (Table 3.2).

In professional football, radiological grading is highly associated with the duration of the convalescent period and correlates with clinical severity. This indicates that an MRI examination can be used to verify the diagnosis, provide an accurate prognosis regarding convalescent period, and monitor healing strains [10, 15, 16, 18, 22].

Table 3.2 MRI classification of hamstring muscle injury [10, 19]

Grade	Findings	Clinical equivalent
0	No visible pathology	Mild
I	Edema without architectural distortion, <5 % of muscle volume involved	Mild
II	Partial rupture with 5–50 % of muscle volume involved	Moderate
IIIa	Complete rupture (Fig. 3.2a–c)	Severe
IIIb	Complete rupture with avulsion fracture	Severe

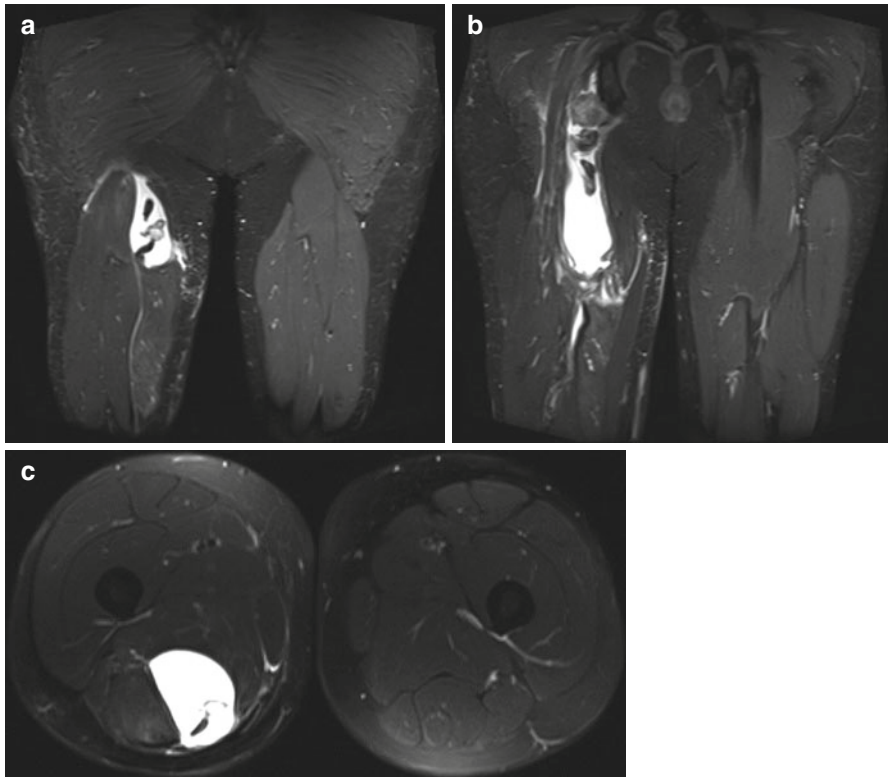


Fig. 3.2 (a) Preoperative MRI (coronal T2 fat sat) of a proximal avulsion of the semitendinosus muscle with hematoma. (b) Preoperative MRI (coronal T2 fat sat) of a proximal avulsion of both the semitendinosus muscle and biceps femoris muscle (long head) with hematoma. (c) Preoperative MRI (axial T2 fat sat) of a proximal avulsion of both the semitendinosus muscle and biceps femoris muscle (long head) with hematoma

The greater part of hamstring injuries are grade 0 or grade 1, without any signs of fiber disruption on MR images [10]. Even though only 26 % of hamstring injuries are objectified by imaging at the initial assessment, nearly 90 % of clinicians use imaging to try and diagnose a hamstring injury in (elite) athletes. When imaging is requested, MRI is used in 40–58 %, US in 29–53 %, and both MRI and US in 7–40 % of cases [14].

3.6 Treatment

The best way to treat a hamstring muscle injury depends on the extent, precise location, and function the muscle is required to regain.

3.6.1 Nonoperative

Mild or moderate hamstring strains are to be treated conservatively [8, 13]. The treatment consists of a phased rehabilitation program [13, 24], as shown in Table 3.3. The first phase focuses on hamstring protection and consists of rest to avoid stretching of the hamstrings and application of ice to minimize pain and inflammation, followed by low intensity pain-free exercises within a limited ROM. These low intensity exercises involve the entire lower extremity and lumbopelvic region in order to develop neuromuscular control and minimize atrophy. Avoiding stretching of the hamstring prevents the development of dense scar tissue that can prohibit muscle regeneration [13].

Table 3.3 Rehabilitation schedule [13, 21]

Phase	I	II	III
Rehabilitation goal	Hamstring protection	Normalize gait Regain of strength Regain of neuromuscular control	Return to sports/ work with good control and no pain
Restrictions	No pain No hip flexion coupled with knee extension Limited ROM	No dynamic stretching No running or impact Limited ROM (avoid end range lengthening)	No sprinting or explosive acceleration movements
Exercises	Balance exercises Isometric exercises of lumbopelvic musculature (core stability)	Neuromuscular control exercises Agility drills Core stability exercises (Submaximal) eccentric strengthening exercises	Sport-specific drills Impact control exercises Agility drills Core stability exercises Eccentric strengthening exercises, with increasing resistance
Interventions	Crutches Application of ice postexercise	Application of ice postexercise	Application of ice postexercise
Progression criteria	Normal gait without pain Low speed jogging without pain Isometric contraction against resistance without pain	Full strength during 1 repetition isometric manual muscle test (prone) without pain Forward/backward jogging at 50 % of maximum speed, without pain	Full ROM, strength and regain of functional abilities without pain or stiffness

Further phases focus on allowing the muscle to heal and regain proper function as rapidly as is reasonably achievable [13]. Phase II consists of therapeutic exercises targeting neuromuscular control, agility, core stability, and eccentric strengthening with increasing speed and intensity [13, 21]. These exercises should be started as soon as the patient is able to walk, jog at very low speed, and perform isometric contraction against resistance without pain. Exercise intensity and ROM are increased based on tolerance and improvement of the patient [13]. It deserves mention that despite a lack of evidence, electrical stimulation is sometimes used. Because stretching exercises may lead to re-injuries [21], they should be performed while avoiding end range lengthening of the hamstrings [13]. Phase III is started when full strength during a 1 repetition maximum effort isometric manual muscle test is reached and the patient is able to jog forward/backward at 50 % of maximum speed. It focuses on return to sports/work, with sport-specific exercises, impact control exercises and increasingly challenging agility drills, core stability exercises, and eccentric strengthening exercises. ROM is no longer limited, but sprinting and explosive acceleration movements should be avoided. Phase III is continued until return to sports/work with full strength, ROM, and regain of functional abilities without pain or stiffness is achieved. Application of ice after rehabilitation exercises is advised to help decrease eventual pain and inflammation [13].

To avoid re-injury, the rehabilitation program will also focus on balancing strength in opposing limbs and muscle groups. High-level clinical trials are needed to further validate the effect of all exercises in the rehabilitation program [20, 21].

Limited evidence suggests that local administration of autologous blood products containing platelet-derived growth factors may enhance healing of muscles and tendons. This platelet-rich plasma (PRP) is best administered by ultrasound-guided injection and is recognized by the World Anti-Doping Agency (WADA) as treatment for tendinopathies while intramuscular injections remain prohibited [18].

Both Actovegin [18, 21] (deproteinized calf blood hemodialysate) and Traumeel S [18] (homeopathic formulation) injections are increasingly popular for the management of acute muscle strains. However, evidence to support the use of these substances is limited to low-quality reports. Controlled trials are needed for confirmation [18, 21].

Non-steroidal anti-inflammatory drugs (NSAIDs), despite their widespread use, have not been proven effective in management of both pain and hamstring function. NSAIDs should not be administered due to the possibility of adverse effects [13, 18, 21].

Intramuscular glucocorticoids are also not recommended. Intramuscular use has been associated with atrophy, disruption of normal muscle architecture, and reduction in tendon collagen strength. Intramuscular use may lead to negative long-term consequences on both muscle regeneration and function [18].

3.6.2 Operative

Surgical treatment is reserved for severe hamstring injuries like avulsions and extensive/recurrent hamstring strains that are resistant to conservative therapy [7, 8, 12, 16]. For avulsions, a reattachment procedure is needed to achieve proper

function in the affected leg. Compared to a conservative approach, surgical repair of tendinous avulsions leads to higher patient satisfaction, higher rate of return to pre-injury level, and greater strength/endurance [12], whereas a conservative approach is associated with functional impairment for a longer period of time [7]. Acute surgical repair is preferred over delayed repair, with higher patient satisfaction, pain relief, strength/endurance, a higher rate of return to pre-injury level, and lower rates of complication and re-rupture [12]. Besides better results, delayed surgical repair is known to be technically more challenging than acute surgical repair [8]. Not infrequently, the ischial nerve lies in the middle of major scar tissue and must be meticulously dissected using a surgical microscope and a nerve stimulator [8].

Surgical repair consists of the use of suture anchors or an interference screw. Auto- or allografts can be used in cases where a large defect between the tendons and the ischial tuberosity prevents anatomic reinsertion [17].

Postoperative rehabilitation is similar to a conservative approach. The difference lies in an additional phase. The postoperative rehabilitation program consists of four phases and is not started until 7–10 days after surgery. Phase I focuses on protecting the repaired hamstring and consists merely of ROM exercises and gait training. As with the conservative approach, application of ice after rehabilitation exercises is advised to help decrease eventual pain and inflammation. Phase II is started 6 weeks after surgery and aims at progression of both speed and amplitude of movement. Core stability and hamstring strengthening exercises are started. Exercises are done with both legs simultaneously in a short arc of motion either at the hip or knee, thereby avoiding lengthened hamstring positions. This means that only concentric and isometric exercises can be performed. Impact and running should also be avoided. Phase II is completed when gait is normalized and functional movements are controlled and painless. Phase III also aims at progression of both speed and amplitude of movement, now one leg at a time with force occurring at both the hip and knee simultaneously. Core stability and hamstring strengthening exercises are continued, carefully supplemented with eccentric strengthening exercises, impact control exercises, and running drills. Phase III is completed when dynamic neuromuscular control is regained and multiplane activities can be carried out without pain or swelling. Also, deficit in leg comparison on Biodex testing (60° and 240° per second) should be less than 25 %. Phase IV is then started and focuses on return to work/sport. All core stability, hamstring strengthening exercises, impact control exercises, and running drills are continued. Sprinting drills, sport-/work-specific balance drills, and proprioceptive drills are started, as well as stretching exercises to correct muscle imbalances. Phase IV is completed when sport-/work-specific movements can be carried out at high velocity with good control and without pain. Also, deficit on both Biodex testing and functional testing profile should be under 10 %. If these criteria are met, the rehabilitation program has successfully been completed [24].

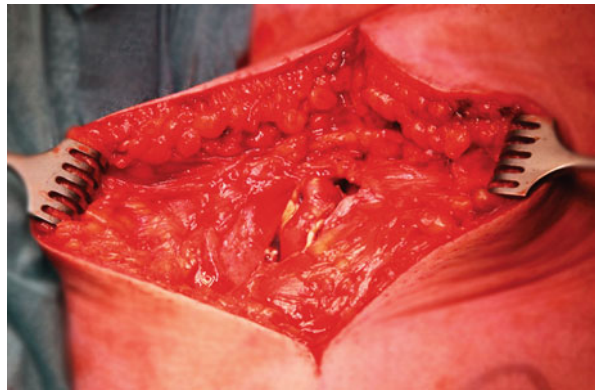
3.6.3 Surgical Technique

The patient should be in prone position, fully anesthetized (Fig. 3.3). The incision is made in line with the hamstring muscle tendons, extending distally from the ischial



Fig. 3.3 Preparations for surgery with patient in prone position

Fig. 3.4 Spreading of craniocaudal incision, incised through dermis, subcuticular tissue, and fascia



tuberosity (approximately 5–7 cm) (Fig. 3.4). A larger incision may be needed to identify retracted muscles. A horizontal incision in the gluteal rim results in a more cosmetically acceptable scar but makes surgery more challenging [8]. The inferior edge of the gluteus maximus is retracted proximally, and the deep fascia of the posterior thigh is subsequently incised parallel to the skin incision. After palpation of the ischial tuberosity, the retracted tendons and the sciatic nerve are identified and mobilized (Figs. 3.5, 3.6, and 3.7) [8]. The ischial tuberosity is then exposed and cleared of scar tissue to insert suture anchors into the tuberosity (Figs. 3.8, 3.9, 3.10, and 3.11) [8, 24]. Sutures are used to attach the retracted tendons to the suture anchors (Fig. 3.12) [8, 24] using a modified Mason-Allen technique. The wound should then be closed in layers, with subcuticular skin closure [8]. Figure 3.13 shows the scar 6 weeks postoperatively. The postoperative position of the suture anchors can be verified by an x-ray (Fig. 3.14).

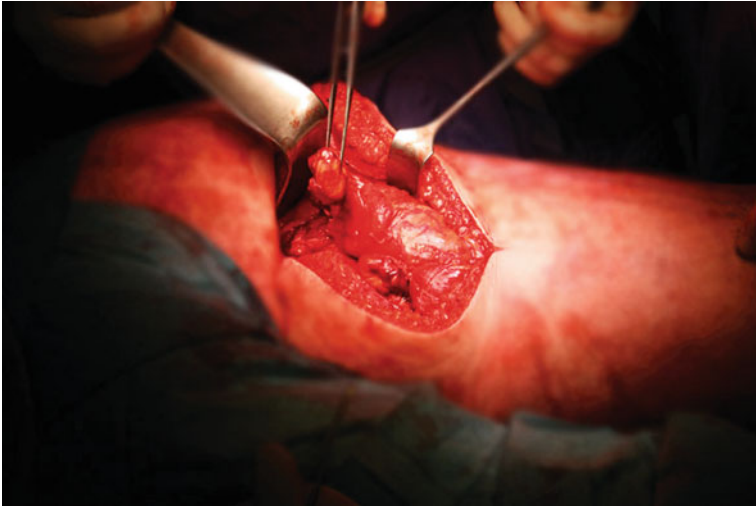


Fig. 3.5 Inspection of posterior thigh compartment, with avulsed hamstrings displayed (both a vertical and horizontal incision was used to be able to identify the avulsed hamstrings)

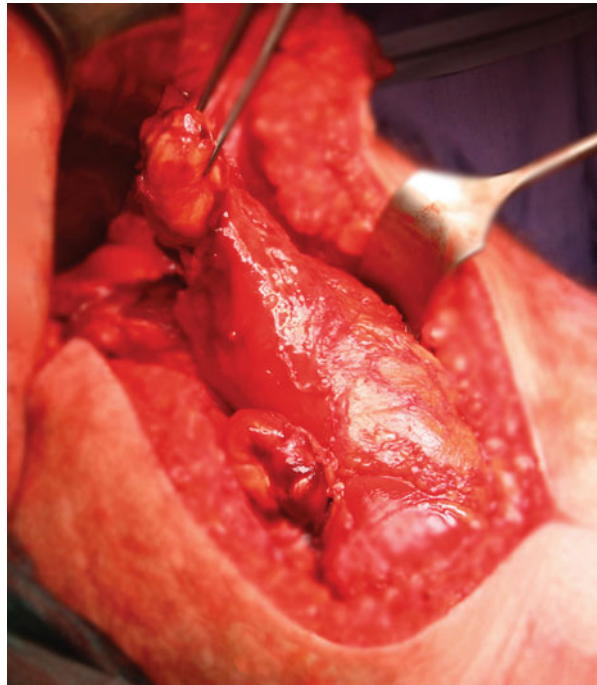


Fig. 3.6 Mobilization of avulsed biceps femoris muscle (long head)

Fig. 3.7 Closer inspection of avulsed biceps femoris muscle (long head)

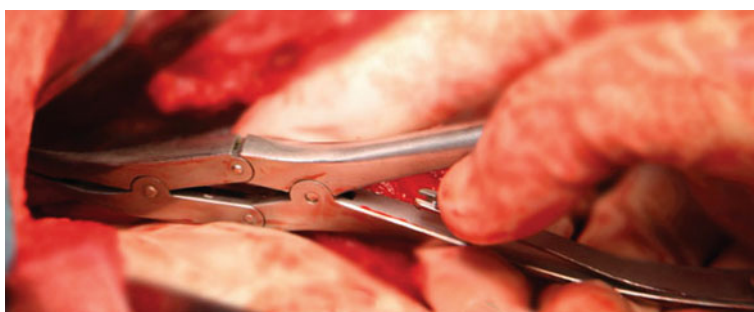
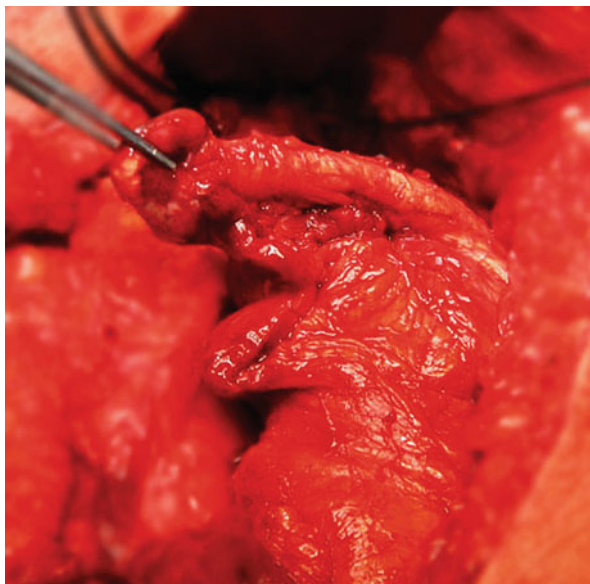


Fig. 3.8 A bone nibbler is used to prepare the ischial tuberosity for reattachment of the avulsed tendons



Fig. 3.9 A surgical drill is used to drill holes for the suture anchors

Fig. 3.10 Ischial tuberosity with holes for suture anchors

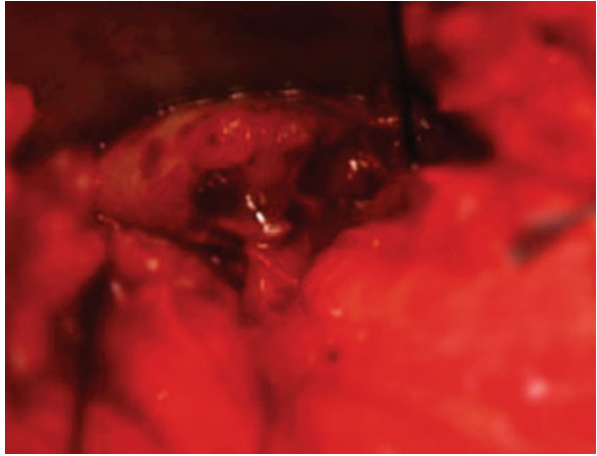


Fig. 3.11 Placement of the suture anchors

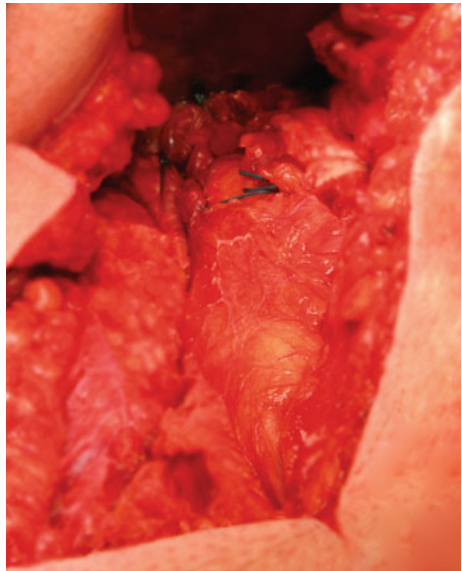


Fig. 3.12 Reattached hamstrings in situ

Fig. 3.13 Scar 6 weeks after operation



Fig. 3.14 Postoperative x-ray to ensure the correct position of the suture anchors (3pcs) into the ischial tuberosity



3.6.4 Findings at Surgery

As mentioned above, surgical repair is mainly reserved for bony or tendinous avulsions. Logically, the tendons are retracted and may be bound by a pseudocapsule or scar tissue. This pseudocapsule is formed by the remains of a hematoma in an acute setting. Scar tissue is formed over a longer period of time in cases where surgery has been delayed. Because the sciatic nerve lies alongside the hamstring origin and muscle bellies, there is risk of entrapment of the nerve by scar tissue. In that case, neurolysis during surgery is required for symptom relief and prevention of iatrogenic injury. Due to this scar tissue, surgery will be substantially more difficult and time consuming than early surgery. On the other hand, if surgery is performed too soon, the surrounding tissue will be edematous and fragile, also resulting in a difficult repair [8].

3.7 Prevention

Hamstring muscle injuries account for extensive absence from competition and training. Prevention of these injuries can therefore be extremely valuable, both to (elite) athletes and their clubs.

Hamstring flexibility programs do not lead to a decrease in incidence of hamstring muscle injuries, whereas eccentric hamstring exercises do lead to a substantial reduction in incidence of hamstring muscle injuries [13, 20]. Other risk factors that can be dealt with are insufficient warming-up and muscle fatigue [20]. Although studies point in the same direction, these findings cannot be generalized due to a lack of high-level clinical trials.

Re-injuries occur frequently and should be prevented by a proper rehabilitation program [13].

Conclusion

Hamstring muscle injury is common in many kinds of sports and often accounts for extensive absence from training and competition. Injury is commonly sustained during eccentric contraction. It is most frequently located proximally and can be divided into the high-speed running type and the stretching type injury. Physical examination should take place within 2 days post-injury and may reveal bruising, focal swelling, pain, and a decrease in both muscle strength and range of motion. MRI and ultrasound can provide detailed information on the nature and extent of the injury. MRI is the best choice to confirm the diagnosis, provide an accurate prognosis, and monitor healing strains. Mild or moderate hamstring strains are preferably treated conservatively, whereas surgical treatment is reserved for severe hamstring injuries including avulsions and recurrent hamstring injuries that are resistant to a conservative approach. Adequate warming-up and eccentric stretching exercises lead to a decrease in risk of injury, while muscle fatigue increases that risk.

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