5 Acute Proximal Hamstring Tendon Avulsions

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Introduction

Proximal hamstring avulsions are relatively uncommon injuries in the general population but occur more frequently with athletic participation at all skill levels. The biceps femoris tendon is the most frequently injured tendon, with injuries most often occurring during the take-off phase of the gait cycle. The semitendinosus tendon is the next most commonly injured proximal hamstring tendon, with strains and tears occurring most often during the swing phase of gait [1]. These injuries are particularly common among athletes who participate in sprinting, hurdling, and water skiing [2].

Mechanism of Injury

The most commonly reported mechanism for proximal hamstring tendon avulsions involves a sudden eccentric contraction of the hamstrings with the hip in flexion and the knee in extension, as may occur during sprinting, hurdling, or water skiing [3, 4]. Because of the increased forces applied, injuries that occur by a water skiing mechanism have been noted to be more severe when compared to those that occur during sprinting [5]. Animal studies have demonstrated that eccentric loads of fatigued muscles result in significantly more damage than isometric or concentric loads [6].

In the case of novice water skiers, the upper torso is forcefully pulled forward, causing subsequent rapid eccentric hip flexion and knee extension against the resistance of the water and ski (Fig. 5.1) [5]. With more advanced water skiers, injuries may occur when the ski tips get caught in the wake during turns or while falling [5]. Additionally, these injuries may occur in sprinters at the time of an acute change in speed or direction or in dancers or gymnasts performing prolonged extreme stretching of the hamstring [6].

Risk Factors for Proximal Hamstring Injury

Multiple risk factors have been reported for proximal hamstring injuries. In the National Football League, the preseason has been identified as the most vulnerable time frame for hamstring injuries due to relative deconditioning and weakness [7]. The most commonly described risk factors include previous hamstring injury [2, 8, 9], poor lower extremity flexibility [10, 11], core instability [12, 13], dehydration, strength imbalance [14, 15], fatigue [1, 16], and an inadequate warm-up

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Fig. 5.1 Water skiing mechanism of injury. As the boat accelerates, the upper torso is forcefully pulled forward, causing subsequent rapid eccentric hip flexion and knee extension against the resistance of the water and ski

[17]. A previous hamstring injury may lead to the formation of weakened scar tissue at the injury site, thereby lowering the capacity of the myotendinous unit to resist secondary injury [16, 18, 19]. Strength imbalance refers to either disproportionate hamstring-to-quadriceps strength in the same limb or the difference in hamstring strength between opposite lower extremities. With regard to the warm-up, increasing muscle temperature in order to prevent injury remains somewhat controversial but may increase the ability of the muscle tendon unit to resist strain [6, 17].

Clinical Presentation

At the time of an acute injury most athletes describe a sudden sharp pain in the posterior thigh or buttock. An audible or palpable pop may be associated with the pain. Classically described during the take-off phase of water skiing when the torso is pulled forward and the skis are pulled against the resistance of the water as mentioned earlier, this injury may also occur with sprinting, jumping, and kicking sports [4, 5, 20]. A smaller subset of individuals may describe progressive hamstring tightness eventually leading to an acute on chronic tear [6]. These injuries may present initially as discomfort with sitting [4, 6].

Differential Diagnosis

The differential diagnosis for proximal hamstring tendon avulsion includes the following [21, 22]:

- Neurologic
  - Lumbar radiculopathy
  - Sciatica
  - Piriformis syndrome
- Vascular
  - Arterial pathology (peripheral arterial disease/pseudoaneurysm/endofibrosis)
  - Venous pathology (pelvic deep vein thrombosis)
  - Compartment syndrome
- Myotendinous
  - Hamstring strain or tear
  - Gluteal muscular tears
- Traumatic/bony
  - Ecchymosis/bruising
  - Morel-Lavallee lesion
  - Ischiogluteal bursitis
  - Insufficiency fracture of pelvis (stress reaction)
  - Acute pelvic fracture
  - Apophysitis
  - Avulsion fracture of the ischial tuberosity
  - Sacroiliac joint pathology

On-the-Field Evaluation

Initial on-the-field or sideline evaluation of a suspected proximal hamstring injury should follow established trauma protocols, particularly if a fracture is suspected. Once the athlete is in a safe area (ideally on the sideline or out of the field of play) a more detailed and focused evaluation should be performed, including a thorough neurovascular examination. If the injury was not witnessed by the clinical evaluator, then the athlete, teammates, or coaches should be questioned to ascertain the mechanism of the injury. Further history taking should include a discussion of any previous injuries to the affected site.

Sideline physical examination should assess the point of maximum tenderness (i.e., origin, musculotendinous junction, mid-muscle belly, or distal hamstring). These areas should be further inspected and probed for any palpable soft tissue defects. Furthermore, the ischial tuberosity should be palpated for possible fracture. Motor strength should be assessed by grading the ability to flex the knee against resistance on a 0–5 scale. Knee flexion strength testing should be performed with the athlete prone and strength tested with knee at 90° of flexion, 45° of flexion, and at 0–10° of flexion. The athlete's gait should be evaluated for pelvic drop, abnormal gait, ability to heel drag, and the ability to initiate a sprint. A stiff-legged gait may also be noted.

Evaluation of the tension of the distal portion of the hamstrings with the patient supine and with the hip and knee flexed to 90° is required for identifying proximal hamstring ruptures. The absence of palpable tension of the distal portion of the hamstrings, referred to as a positive bowstring sign, may be present. This sign suggests that there has been excessive lengthening of the proximal part of the tendons or complete proximal hamstring rupture [23].

Physical Examination

Physical examination in the office setting includes a repeat neurovascular examination to rule out lumbar spine and sciatic nerve pathology as well as any peripheral vascular concerns. The neurologic examination should also include assessment of the function of the tibial and peroneal branches of the sciatic nerve [21, 24]. When affected the athlete may experience a foot drop with possible ankle eversion weakness [25]. Additionally, a stiff-legged or antalgic gait may be noted when the patient is observed walking [4].

The thigh and buttock should be inspected with the patient prone. The evaluation should note any visible or palpable soft tissue defect. Severe ecchymosis is commonly present at the posteromedial thigh in the first 1–2 weeks following an acute tendon rupture (Fig. 5.2). The point of maximal tenderness should again be determined by palpation including palpation of the ischial tuberosity. Strength testing should again be performed prone with resisted knee flexion at 0–10°, 45°, and 90° of flexion and graded as described above.

Fig. 5.2 Photograph of ecchymosis of the posterior thigh 5 days after proximal hamstring rupture

The Reverse Plank test is a specific test that should be performed to evaluate hamstring function [4, 26]. This test (Fig. 5.3) is performed by having the patient supine and resting on the heels and flexed elbows. The core is contracted and the buttocks are lifted off the floor or examination table while the uninjured lower extremity is lifted forward. Pain and inability of the injured limb to elevate the buttocks off the floor is indicative of a hamstring injury. The standing heel-drag test is performed by having the patient drag the heel of the affected lower extremity against the friction of the floor in an anterior to posterior direction. The test is performed bilaterally with a positive result occurring when pain or discomfort is elicited at the ischial tuberosity of the injured limb [26].

Multiple other special provocation tests have been described to evaluate for hamstring injuries [6]. The Puranen–Orava test (Fig. 5.4a) is performed with the patient standing with the hip flexed to 90° and the knee fully extended [6].

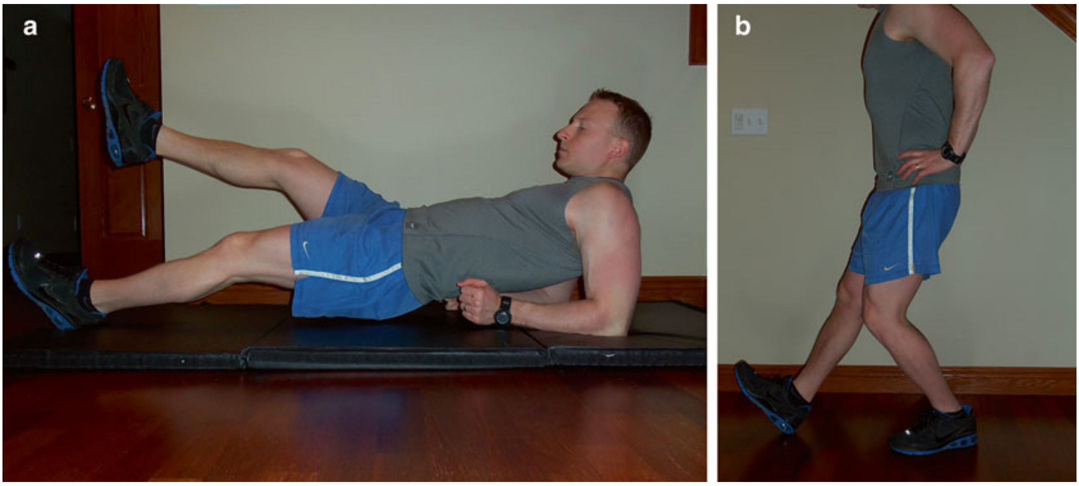

Fig. 5.3 (**a**) Reverse plank test. Examinee is supine and resting on the heels and flexed elbows. The buttocks are lifted off the floor or table while the uninjured lower extremity is lifted forward. Pain and inability of the injured limb to elevate the buttocks off the floor are indicative of a hamstring injury. (**b**) Standing heel-drag test. Examinee drags the heel of the affected lower extremity against the friction of the floor in an anterior to posterior direction. Test is positive when pain is reproduced at the ischial tuberosity

The examinee's heel is held on a support by the examination table, a chair back, or railing. For the bent-knee stretch test the patient is supine and the hip and knee of the injured extremity are maximally flexed [6]. The examiner then slowly passively extends the knee. The modified bent-knee stretch test (Fig. 5.4) is also performed with the patient supine. The examiner maximally flexes the hip and knee and then rapidly extends the knee. For all tests described above, tendinosis, strain, or potential rupture of the hamstring is indicated by increased posterior thigh pain with extension of the knee. This series of examination tests has shown moderate to high validity and reliability for identifying hamstring injuries [6, 27].

Imaging

Radiographs

Imaging evaluation in a patient with a suspected proximal hamstring injury should include an anterior/posterior X-ray view of the pelvis [4, 28]. Orthogonal views should also be obtained of the femur of the injured limb to confirm there is no associated proximal femur fracture present. Radiographs are typically normal but may be reveal an avulsion fracture of the ischial tuberosity [4, 28].

MRI

If radiographs are normal, magnetic resonance imaging (MRI) is recommended for making an accurate diagnosis. T2-weighted MRI series further assist in determining the pattern and severity of soft tissue injury including the number of tendons injured, complete versus partial rupture, chronicity, and the amount of tendon retraction (Fig. 5.5). Chronicity of the injury can be determined on T2 MRI based on the amount of fibrosis present [6, 29]. Additionally, MRI can determine the degree of soft tissue damage by defining the dimensions of abnormal T2 signal within and around the tendon substance, percentage of abnormal cross-sectional tendon substance, and extent of increased T2 signal intensity [30]. For proximal hamstring injuries, images should capture the ischial tuberosities and proximal thighs. Partial-thickness tears of the proximal hamstring complex may also be identified by a linear signal at the tendon–bone interface present on axial T2 images. This linear, crescent-shaped signal is referred to as the "sickle-sign" [26].

Fig. 5.4 (**a**) Puranen–Orava test. (**b**, **c**) Bent-knee stretch test. (**d**, **e**) Modified bent-knee stretch test

Ultrasonography

Recently ultrasound has increased in popularity and usefulness for identifying and classifying proximal hamstring ruptures. Ultrasonography has been demonstrated to be highly accurate in the acute setting for determining the extent and location of a hamstring tear [6, 18, 31]. This modality provides high-resolution imaging allowing for direct correlation with clinical examination and more immediate imaging [18]. The advantages of this technique include its relative inexpense, its high sensitivity and specificity, and its increasing availability in clinics and emergency department settings. The greatest disadvantage of using ultrasound for diagnosis of

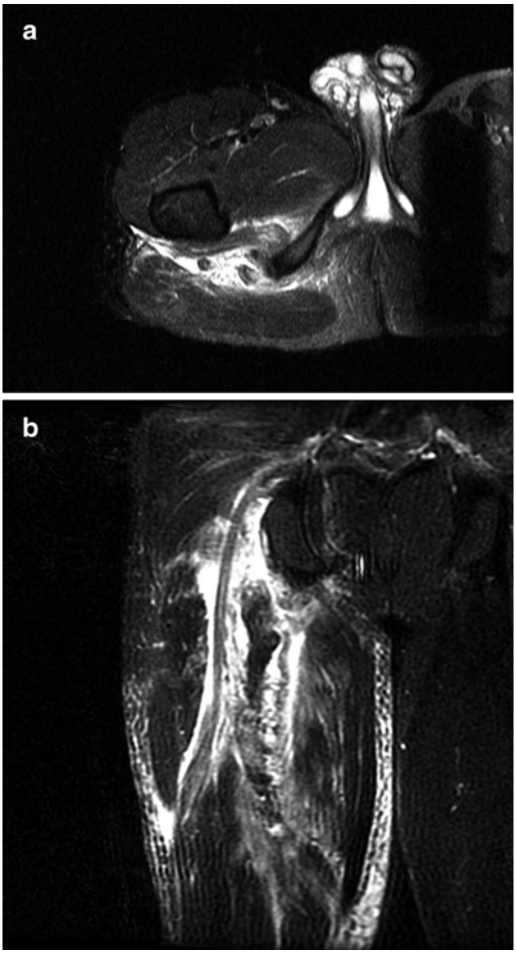

Fig. 5.5 (**a**, **b**) Axial and coronal cut T2 MRI demonstrating acute complete proximal hamstring avulsion tear with retraction

proximal hamstring tendon avulsion is that its accuracy is often dependent on the operator's level of experience (Fig. 5.6).

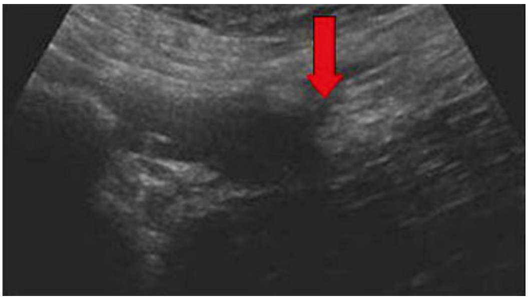

Fig. 5.6 Longitudinal ultrasound image demonstrating retracted proximal hamstring avulsion rupture. *Arrow* points to biceps femoris stump

Table 5.1 Classification of proximal hamstring tendon injuries[a]

• Type I:	Bony avulsion
• Type II:	Proximal MTJ tear
• Type III:	Incomplete avulsion
• Type IV:	Complete avulsion—w/o retraction
• Type V:	Complete avulsion—retracted A. + sciatic nerve symptoms B. − sciatic nerve symptoms

[a] Adapted from [33]

Classification

Hamstring injuries have been classified based on the anatomic site, pattern, and severity of the injury in the acute stage, as assessed by MRI or ultrasound [2, 6, 30, 32, 33]. Wood et al. described a clinical and anatomic classification system based on pattern of the tear and patient symptoms [1] (Table 5.1). Shelly and associates have described an MRI grading system for muscle injury that is commonly used to categorize hamstring injuries. In this system grade 1 is defined by a T2 hyperintense signal about a tendon or muscle without fiber disruption, grade 2 as a T2 hyperintense signal around and within a tendon with fiber disruption less than half the tendon width, and grade 3 as disruption greater than half its width [34]. Neither clinical nor radiologic classifications, however, have been precisely correlated with time to return to play after a hamstring injury.

A more detailed MRI scoring system has been devised by Cohen et al. [35] based on eight features. These include (1) player age, (2) number of muscles involved, (3) location of injury, (4) presence of insertional damage, (5) percentage of cross-sectional muscle involvement, (6) length of muscle retraction, (7) long-axis T2 sagittal plane signal abnormalities, and (8) presence of chronic changes. Recovery time >2 to 3 weeks was associated with multiple-muscle injury, >75 % cross-sectional involvement, presence of retraction, circumferential edema, and an MRI score of >15 [35]. This scoring system was found to be highly predictive of time missed from athletic participation [6].

Ischial Tuberosity Avulsion Fracture

Avulsion fractures of the ischial tuberosity typically occur in younger athletes particularly in the pediatric population as the child approaches skeletal maturity [36–38]. As with tendinous avulsions, these injuries typically result from a sudden forceful flexion of the hip joint while the knee is extended and the hamstring is contracted. Patients report sudden pain of the proximal, posterior thigh and a palpable or audible crack following a violent muscle contraction [22]. Clinical presentation typically includes localized pain and swelling, limited hip motion, and pain with sitting. Radiographs of the pelvis in the anterior to posterior plain should be performed for patients with suspected ischial tuberosity fracture and correlative clinical findings (Fig. 5.7). Fractures may be nondisplaced to widely separated with or without comminution. Occasionally a pseudarthrosis or an enlarged ischial mass may develop leading to chronic pain [39]. When radiographs are inconclusive, MRI or ultrasound may be required to evaluate soft tissue injury of the proximal hamstring as described above. As with all fractures, prompt and accurate diagnosis is essential for providing optimal treatment.

Because of the limited literature on the treatment of ischial tuberosity avulsion fractures, there is no clear algorithm for the management of this injury [22, 37, 40]. Nonoperative treatment with activity modification and use of a cushioned seat are the mainstays of treatment for the vast majority of patients. An adequate period of rest and activity modification facilitates the best outcomes from conservative management [41]. Failure to heal with nonoperative treatment and/or displacement of greater than 2 cm are relative indications for surgery. However, there is no clearly defined amount of displacement that confirms the need for surgery [41]. A multitude of surgical options have been described to treat avulsions fractures including open reduction and internal fixation [22] and excision of the bony fragment [39] with or without repair of soft tissue to bone [41]. Potential complications of conservative treatment include nonunion of the avulsion fractures and “hamstring syndrome” in which shortening and fibrosis develop at the origin of the hamstrings [42]. An adequate period of rest and modified training seems to be important to facilitate optimal outcome of conservative treatment [41].

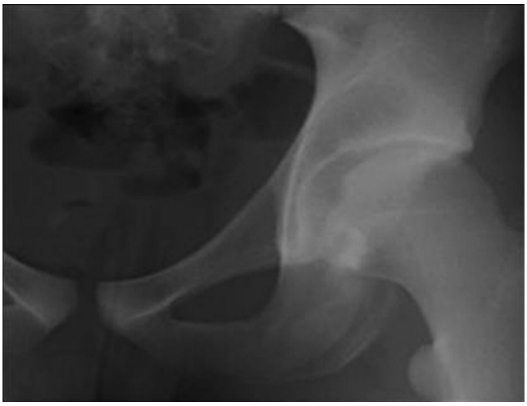

Fig. 5.7 AP pelvis radiograph demonstrating right ischial tuberosity avulsion fracture

Most authors recommend operative treatment in fractures with displacement greater than 2 cm [41]. Ferlic et al. found that in the acute setting operative treatment led to excellent outcomes for displacement of fractures greater than 1.5 cm [41]. Gidwani and associates recommend early operative treatment in patients with displacement of more than 1 cm [43]. Multiple surgical options have been utilized including plate fixation and screw fixation [22, 43]. Surgical approaches via the gluteal crease or a modified Kocher–Langebeck approach may be performed with the patient placed prone and flexed or in the lateral decubitus position with the injured side positioned up and the limb draped free. Figure 5.8 demonstrates a displaced ischial tuberosity fracture post open reduction and internal fixation. Postoperative rehabilitation follows similar protocols as will be described later for tendinous avulsions.

Fig. 5.8 AP pelvis radiograph following fixation of ischial tuberosity avulsion fracture

Table 5.2 Treatment recommendations for proximal hamstring tendon avulsions

Single-tendon avulsion (with retraction 1–2 cm)	
	Nonoperative treatment
	Return to sport at approximately 6 weeks postinjury
Two-tendon rupture: Controversial (literature not well established)	
	Nonoperative treatment for older (>50 years of age) and low-demand patients
	Surgical repair for: – Young patients (<50 years of age) – Athletically active patients – Tendon retraction >2 cm
Three-tendon avulsion:	
	Surgical repair

Management of Proximal Hamstring Avulsions

As with ischial tuberosity avulsion fractures, early diagnosis and prompt treatment are the keys to the management of proximal hamstring avulsions. Activity level of the patient affects treatment decision-making with surgery being recommended more often for highly active patients. Delay in surgical treatment allows for greater tendon retraction making repair more difficult and increasing the risk of complications and inferior outcomes [44, 45]. Long-term sequelae of a neglected hamstring avulsion include pain, weakness, poor endurance, and sciatica due to tethering of the retracted muscle to the sciatic nerve [46]. A recommended treatment protocol is shown in Table 5.2.

Nonoperative Management

Nonoperative treatment is appropriate for proximal hamstring injuries involving only one tendon or if multiple tendons are involved but retraction is minimal [4]. This option is reserved for one- or two-tendon ruptures with less than 2 cm of retraction [4]. Nonoperative treatment is less successful for more significant injuries including complete three-tendon tears regardless of the extent of retraction [4, 6, 44, 45]. Less active patients, those with medical comorbidities, and patients unable to comply with postoperative rehabilitation are also indications to manage these injuries nonoperatively [6]. One notable complication of nonoperative treatment is hamstring syndrome. This is characterized by posterior buttock pain, discomfort with sitting, and worsening pain when performing hamstring stretching and strengthening exercises [6, 47].

Nonoperative management consists of rest, activity modification, anti-inflammatory medications and physical therapy. Once pain from the injury resolves core (abdominal and paraspinal), hip, and quadriceps exercises are added to the rehabilitation protocol [48]. Modalities proposed to improve symptoms and potentially speed recovery include ultrasound, shockwave therapy, and electrical stimulation [49]. These injuries may take up to 6 weeks for the tendon to heal via fibrosis to the intact tendons, often allowing the initiation of limited activity at that point. However, symptoms from many tears managed nonoperatively can persist beyond the normal healing times. Full return to sports participation is permitted when pain has resolved and strength has returned to >90 % of the contralateral hamstring [48].

Operative Management

Surgical Indications

Surgical indications suggested by multiple authors for proximal hamstring injuries include those that involve all three tendons (semitendinosus, semimembranosus, and the biceps femoris long head) as well as some two-tendon tears with more than 2 cm of retraction [4, 6, 23, 33, 44, 47, 50–52]. Additionally, operative treatment is recommended for partial tears when nonoperative treatment is unsuccessful [4, 23, 33].

Timing of Repair

Proximal hamstring avulsions that require surgery are best managed within 4 weeks of injury [6]. Some studies have suggested that delayed repair is associated with poorer results and reduced hamstring strength and endurance [5, 33, 50], while other studies have shown no difference [23, 24, 51]. Brucker et al. reported on eight patients, six of whom had surgery within 2 weeks after the injury, one at 9 weeks, and one at 22 weeks. Those authors found no difference in postoperative isokinetic testing between the groups [24]. Likewise, Klingele et al. found no difference in postoperative isokinetic testing between chronic (i.e., repair more than 4 weeks after injury) and acute (i.e., repair less than 4 weeks after injury) surgical repairs [51]. Sarimo and associates reported on 41 patients with proximal hamstring injuries, 29 of whom had good or excellent results after having surgery an average of 2.4 months from the time of injury. The remaining 12 patients had moderate or poor outcomes at an average surgical delay of 11.7 months from injury [23, 50].

Surgical Technique Options

Endoscopic Repair

There have been many series and descriptions of open surgical techniques for proximal hamstring repair but very few for endoscopic techniques [53, 54]. With the significant increase in use of the arthroscopy of the hip proximal hamstring repair via this technique is a developing option for repair. In experienced hands, this procedure allows for complete exposure of the posterior aspect of the hip in a safe, minimally invasive fashion. The expected benefits of this approach are no requirement for elevation of the gluteus maximus and greater ability to protect the sciatic nerve [53, 54].

The technique positions the patient prone. Two endoscopic portals are created, 2 cm medial and lateral to the palpable ischial tuberosity, respectively. A 30° arthroscope is inserted in the lateral portal, and an electrocautery device is placed in the medial portal to remove any remaining fibrous tissue from the bony attachment. The hamstring footprint is then undermined, and the lateral ischial wall is debrided with an oscillating shaver. The devitalized tissue is removed, and a vascular bone bed is created in preparation for suture anchor insertion. A third portal is created approximately 4 cm distal to the tip of the ischium. Once the suture anchors have been drilled and inserted into the bone bed, a suture passing device is then used for the repair. Once this point is reached, the principles of repair are analogous to those used in arthroscopic rotator cuff repair [53].

One concern for the endoscopic approach includes fluid extravasation into the pelvis as a result of the fluid used in the distension of the potential space around the hamstring tendon. Additionally, iatrogenic injury to the sciatic, posterior femoral cutaneous, and inferior gluteal nerves remains a risk. However, given that no retraction is required, these risks are theoretically lessened [53, 54].

Preoperative Planning and Positioning for Open Repair

Open repair of a proximal hamstring avulsion requires that the patient is fully anesthetized and positioned prone with the trunk in approximately 20° of flexion at the waist (Fig. 5.9a, b) [6, 55]. The affected lower extremity is draped free to allow access to the gluteal crease and unrestricted knee flexion. Preparation and draping of the limb may be more easily performed by hanging the limb from a fixed suspensory device such as an IV pole with a padded stirrup to hold the limb elevated by the ankle while the limb is cleansed [46].

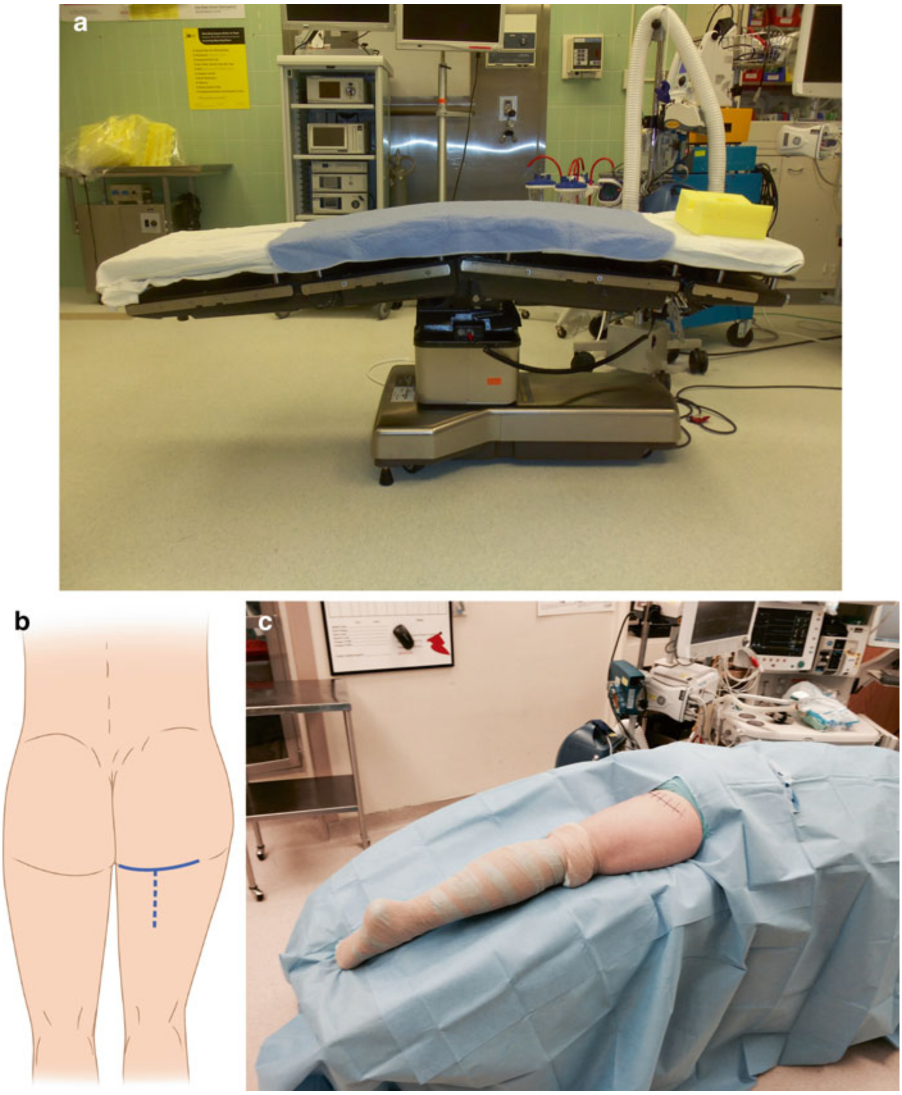

Fig. 5.9 (**a**) Operative table position for exposure of gluteal crease: 20° of flexion. (**b**) Transverse incision is made in the inferior gluteal crease to improve cosmesis and access to the retracted tendons. (**c**) Intraoperative photograph of patient, position, draping, and planned incision

Surgical Anatomy and Open Surgical Approach

Surgical approach to the avulsed proximal hamstring tendons and the ischial tuberosity is performed through a transverse incision at the gluteal crease (see Fig. 5.9b, c). Longitudinal and T-shaped incisions have been described but are typically less cosmetically pleasing [51, 55]. The dissection proceeds through the subcutaneous tissue to expose the gluteal fascia taking care to protect the posterior femoral cutaneous nerve and its branches. The gluteal fascia is then incised in line with the skin incision. The gluteus maximus is elevated and retracted superiorly or split over the ischial tuberosity to expose the hamstring fascia [6]. The hamstring fascia is then split longitudinally to expose the torn tendons. When the repair is not performed acutely, scar tissue may envelop the damaged tendons giving the impression of intact tendons. Scar tissue is excised and any seroma or hematoma is evacuated from the surgical field. The remaining tendons are then mobilized, debrided, and tagged with suture for later repair.

The sciatic nerve may be exposed and a neurolysis performed at this time if the patient displays signs of sciatic nerve injury preoperatively. Otherwise, the nerve may be protected by retracting the hamstring tendons laterally as the ischial tuberosity is exposed and prepared [6]. A periosteal elevator, small rongeur, or curette is used to clear the soft tissue remnant from the lateral aspect of the ischial tuberosity [55]. A bleeding bone bed is then prepared at the insertion site to increase healing potential at the bone–soft tissue interface and allow application of the fixation devices [55]. A motorized burr is not recommended for this step due to risk of injury to the nearby neurovascular structures. Alternatively, a small osteotome may be used to create longitudinal stripes at the insertion and prepare the vascular bed. The bone should not be completely decorticated as this may lead to pullout of the fixation devices [6].

Fixation

For fixation of reattached tendons, suture anchors are placed in an "X" pattern into the ischial tuberosity perpendicular to the facet of the hamstring origin (Figs. 5.10 and 5.11). The semimembranosus tendon is located anterior and lateral to the long head of the biceps femoris and the semitendinosus tendons [55, 56]. The semimembranosus footprint is crescent shaped and lies lateral to the semitendinosus and biceps femoris footprint [56]. The semitendinosus and biceps femoris share an oval-shaped footprint 2.7 cm long and 1.8 cm wide [56] (Fig. 5.12). Five anchors inserted into the anatomic location of the proximal hamstring tendons is recommended [55]. The knee is held flexed at 30–60° to decrease tension on the repair. The sutures are then passed through the tendon in a similar "X" configuration and tied in a horizontal mattress fashion from inferior to superior [55]. Chronic tendon ruptures may require an allograft soft tissue bridge due to retraction of the tendons distally away from the

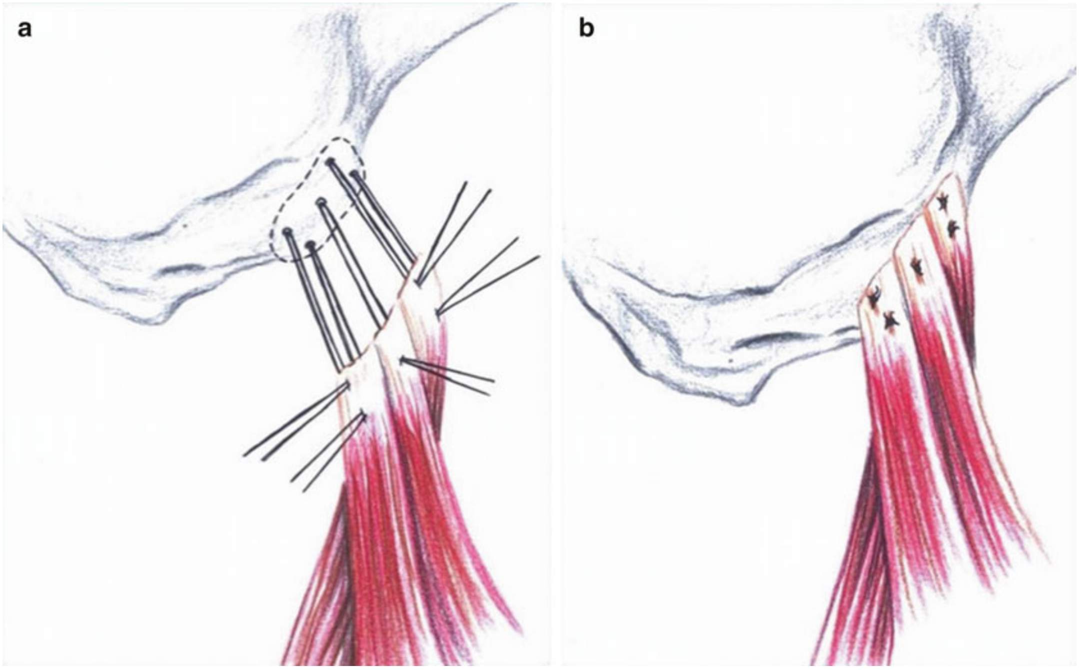

Fig. 5.10 (**a**) X configuration of suture anchors placed at the ischial tuberosity with sutures passed through the tendons. (**b**) Sutures tied distal to proximal securing tendon to bone. Reprinted with permission from Dr. James Bradley

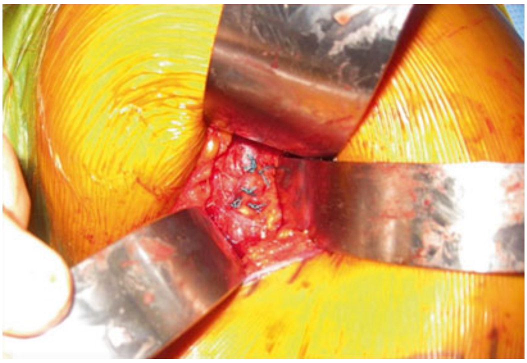

Fig. 5.11 Intraoperative photograph demonstrating the X configuration of suture anchors following repair of proximal three-tendon hamstring avulsion tear

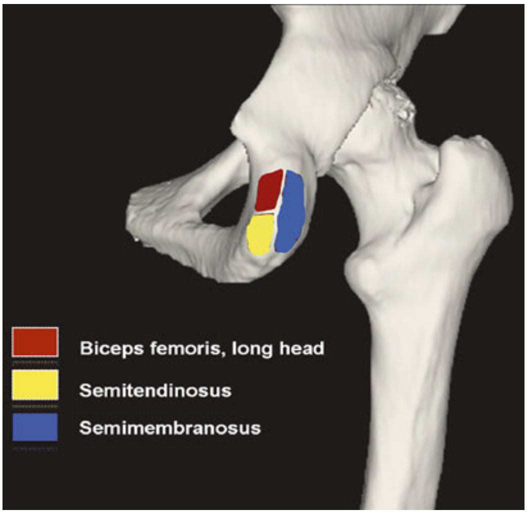

Fig. 5.12 Three-dimensional CT scan of the right hemipelvis demonstrating the insertion sites of the proximal hamstring tendons. Ahmad CS, Redler LH, Cicotti MG, Maffulli N, Longo UG, Bradley JP, American Journal of Sports Medicine (vol. 41, issue 12) pp. 2933–2947, copyright © 2013 by SAGE Publications. Reprinted by permission of SAGE Publications

tuberosity. This gap may be covered by employing an Achilles tendon allograft [6].

Risks and Complications

Intraoperative complications most commonly involve transient neuropraxias of the sciatic nerve. These neurologic symptoms present as weakness in the operative extremity with burning pain down the affected leg [6]. Other nerves that can be potentially injured at the time of surgery are the posterior femoral cutaneous nerve and the inferior gluteal nerve. Postoperative infections are a major concern at this site because of the proximity of the surgical field to the genitourinary tract and the rectum [6].

Commonly reported surgical complications after proximal hamstring tendon repair include the following:

- Neurologic injury (neuropraxia)
  - Sciatic nerve
  - Posterior femoral cutaneous nerve
  - Inferior gluteal nerve
- Poor wound healing
- Hematoma/seroma
- Tendon re-rupture
- Sitting or activity-related pain
- Muscle weakness
- Deep vein thrombosis
- Infection
- Ischial tuberosity fracture

Postoperative Rehabilitation

An appropriately guided postoperative rehabilitation program is essential for obtaining ideal outcomes following proximal hamstring repair. The patient is initially placed into a custom-fit hip orthosis at 30–40° of hip flexion and kept touch down weight bearing for 2 weeks [57]. Weight bearing is then advanced to 25 % of full over the following 3 weeks. Passive range of motion of the knee and hip is started after 2 weeks, and active hip range of motion begins after 1 month. Hip flexion is advanced by 10° each week for the first 6 weeks while the patient wears the hip-knee orthosis [55].

Full weight bearing is initiated after 6 weeks, and the hip orthosis is discontinued at that time. Gait training and aquatic therapy are begun at this point with isotonic exercises, core strengthening, and closed chain exercises being introduced between 6 and 8 weeks [6, 55]. Hip range of motion is also advanced at this point with caution taken at full flexion. Dynamic training and isometric strengthening begin at 8 weeks after surgery, and at 10 weeks an isometric strength evaluation is performed with the knee at 60° of flexion [55].

Dry land jogging and sport-specific training begin between 10 and 12 weeks. A fully isokinetic evaluation is recommended at 12 weeks at 60°/s, 120°/s, and 180°/s. These results are compared with the contralateral leg and should be at least 80 % of that of the uninjured limb prior to return to sports [6, 55].

Return to Sport

Return to sport is permitted once the isokinetic testing of the operative limb equals 80 % of the nonoperative limb. This level is typically reached between 6 and 10 months [6, 23, 55, 58]. The percentage of abnormal muscle area and the volume of injury has been correlated most precisely with time to return to sport [30]. Askling et al. prospectively evaluated 18 elite sprinters with clinically diagnosed hamstring injuries and serial MRI evaluations at 10, 21, and 42 days after injury [2]. Those authors found that proximal hamstring injuries demonstrated most prolonged time to return to play [2].

Postoperative Treatment Outcomes

Most series report that return of strength ranges from 60 to 90 % of the contralateral leg, with up to 95 % of patients or more reporting good to excellent subjective results after surgical repair [6, 23, 24, 45, 59–62]. Klingele and Sallay reported that seven of nine athletically active patients who had complete proximal hamstring ruptures returned to their sports activities at an average of 6 months following repair [51]. Sarimo et al. reported on 41 patients with complete proximal hamstring avulsions and found that 20 of 27 recreational athletes returned to their preinjury level of sports activities within 4–10 months [23, 50].

Wood et al. reported on 72 patients who underwent proximal hamstring repairs. In their series 80 % of the patients had returned to their preinjury level of sports by 6-month follow-up postsurgery with mean postoperative isotonic hamstring strength being 84 % of the contralateral limb [33, 63]. Lempainen et al. reported on 47 athletes who had partial tears of the proximal origin of the hamstrings. Forty-two of the 47 were initially treated nonoperatively with unsatisfactory results. Forty-one of those 42 patients returned to their preinjury level of sports activity after an average of 5 months following surgical repair [63].

Regarding patient-reported outcomes, Konan et al. reported on ten semiprofessional or professional athletes with proximal hamstring tears. Their patients described subjectively excellent functional results by 12 months with hamstring peak torque reaching 82.78 % of the contralateral side by 6 months. Additionally, Cohen and Bradley et al. found in a series of 52 patients that 98 % were satisfied with their outcome after surgery. In their study objective measures such as the Lower Extremity Functional Scale and custom Marx score showed a statistical difference between acute and chronic repairs, with acute repairs exhibiting improved outcomes [45].

Future Directions

Tissue Engineering

In recent years, tissue engineering and cell therapy have gained increasing utilization among elite level athletes. Much research regarding its efficacy has been directed toward skeletal muscle and myotendinous units [20, 23]. These branches of regenerative medicine involve stem cells to reconstitute tissue and stimulate healing of muscle [6]. Though further research is necessary to identify the mechanisms of activation of mesenchymal progenitor cells derived from traumatized muscle to promote wound healing after injury, the potential therapeutic effects are broad and likely to remain the topic of discussion and research for some time [64].

Platelet-Rich Plasma

Platelet-rich plasma products are a source of biologically active molecules that have the potential to improve the healing process in soft tissue injuries [65, 66]. The results published by Mejia et al. showed an earlier return to play in National Football League players who were administered autologous conditioned plasma for hamstring injuries. Though its effect and mechanism remain debatable, platelet-rich plasma has been widely described for the management of many musculoskeletal injuries, including hamstring tears, because it has been found to be safe and is relative easy to obtain [6, 65–67].

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