Original Research

Surgical Management of Recurrent Musculotendinous Hamstring Injury in Professional Athletes

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Background: Hamstring injury is the most common muscular lesion in athletes. The conservative treatment is well described, and surgical management is often indicated for proximal tendinous avulsions. To our knowledge, no surgical treatment has been proposed for failure of conservative treatment in musculotendinous hamstring lesions.

Purpose: To describe the surgical management of proximal and distal hamstring musculotendinous junction lesions in professional athletes after failure of conservative treatment.

Study Design: Case series; Level of evidence, 4.

Methods: A consecutive series of 10 professional athletes, including 4 soccer players, 4 rugby players, and 2 handball players, underwent surgical intervention between October 2010 and June 2014 for the treatment of recurrent musculotendinous hamstring injuries. All athletes had failed at least 3 months of conservative treatment for a recurrent musculotendinous hamstring injury. Surgical resection of the musculotendinous scar tissue was performed using a longitudinal muscular suture. Lower Extremity Functional Scale (LEFS) and Marx scores were obtained at the 3-month follow-up, and a final phone interview was completed to determine recurrence of hamstring injury and return to previous level of play.

Results: The mean age at surgery was 25.2 years (range, 19-35 years). The musculotendinous hamstring lesions involved 8 semitendinosus and 2 biceps femoris, with 6 injuries located proximally and 4 distally. Conservative treatment lasted a mean 5.1 months (range, 3-9 months) after last recurrence, and the patients had an average of 2.7 (range, 2-5) separate incidents of injury recurrence before surgical intervention was decided upon. At the 3-month follow-up, all patients had Marx activity scores of 16 and LEFS scores of 80. All 10 patients returned to the same level of play at a mean 3.4 months (range, 2-5 months). At a mean follow-up of 28.7 months, none of the athletes had suffered a recurrence. No surgical complication was encountered.

Conclusion: In cases of failed conservative treatment of musculotendinous hamstring lesions, surgical intervention may be a viable treatment option in professional athletes and allows the patient to return to the same level of play.

Keywords: hamstring; musculotendinous lesion; sports injuries; professional athlete

Historically, the term *hamstring* is derived from the trade of butchering. Pig carcasses were hung up by these tendinous muscles in the thigh of the ham for slaughtering. Additionally, the verb *to hamstring* means "to disable or to render useless." This is testament to the importance of the hamstrings in both daily life and recreational activities.[30]

The hamstrings are made up of 3 separate muscles: the semimembranosus, semitendinosus, and biceps femoris, the latter with a long and short head. The tendon of origin of the semimembranosus muscle arises from the triangular lateral facet of the ischial tuberosity; yet just below the tuberosity it has the form of a flat band, which lies in the coronal plane, on the deep aspect of the biceps and semitendinosus. The biceps femoris and semitendinosus share

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TABLE 1
Surgical Outcomes[a]

Patient	Sex	Age, y	Side	Location	Tendon Involved	Sport	Number of Prior Injuries	Months From First Injury to Surgery	Months From Surgery to Return to Play	Follow-up, mo
1	M	35	L	Proximal	BF	Handball	5	8	2	17
2	M	25	R	Proximal	ST	Handball	2	3	3	7
3	M	25	L	Proximal	ST	Rugby	3	7	4	60
4	M	21	L	Proximal	BF	Rugby	2	3	5	45
5	M	22	R	Proximal	ST	Rugby	2	3	3	32
6	M	26	L	Distal	ST	Rugby	5	9	3	46
7	M	25	R	Distal	ST	Soccer	2	3	4	32
8	M	26	R	Proximal	ST	Soccer	2	3	3	35
9	M	28	R	Distal	ST	Soccer	2	4	4	7
10	M	19	R	Distal	ST	Soccer	2	8	3	6

[a]BF, biceps femoris; L, left; M, male; R, right; ST, semitendinosus.

a common tendon of origin, which arises from the medial facet of the ischial tuberosity.[26]

The hamstring spans both the hip and knee joints. During certain activities, these 2 joints may be moving in opposite directions, which contributes to a predisposition to an eccentric injury. In addition, the hamstrings have more abundant type II muscle fibers, which give explosive force compared with the quadriceps but may further predispose the hamstrings to injury.[34]

Hamstring injury is the most common muscular lesion in athletes.[8] The most commonly injured muscle in the hamstring group is the biceps femoris, and the injuries are usually found at the muscle-tendon junction.[11] The conservative treatment is well described with good results, mainly in nonprofessional populations, and consists of rest, nonsteroidal anti-inflammatory drugs (NSAIDs), physical therapy, and an exercise program.[7,29] Steroid injection has also been proposed for hamstring injuries as a treatment to decrease the symptoms but not the rate of recurrence.[24]

Rarely is surgical intervention performed, except in large, displaced proximal tendinous avulsions, but with good results.[35] To our knowledge, no surgical treatment has been proposed for failure of conservative treatment for proximal and distal musculotendinous hamstring lesions. The purpose of this article was to describe the surgical management of recurrent musculotendinous hamstring lesions after failure of conservative treatment in professional athletes.

METHODS

Between October 2010 and June 2014, 10 professional athletes with a mean age 25.2 years (range, 19-35 years) underwent surgical intervention for the treatment of recurrent musculotendinous hamstring injuries. The diagnosis of recurrence was made on subsequent magnetic resonance imaging (MRI) examinations confirming the location of the new tear at the previous injury site. Among the professional athletes, there were 4 soccer players, 4 rugby players, and 2 handball players (Table 1).

All athletes were treated conservatively after the first injury with rest, NSAIDs, and physical therapy. Once gait was normalized and hamstring strength was 50% of the contralateral leg, concentric and eccentric loading of the hamstrings with exercises such as straight-leg deadlifts and Nordic hamstring exercises commenced. Increased stretching was also initiated. This phase was completed when the hamstrings obtained a 5 out of 5 in manual muscle testing and forward/backward jogging was pain free. The final phase focused on increasing functional exercises and strengthening in a lengthened state. Plyometrics, high-level balance activities, and sport-specific drills were performed. After completion of this stage, the athlete should have obtained full mobility, strength, and coordination to return to full sport participation without restrictions. All athletes had failed at least 3 months of this conservative protocol initiated for a recurrent musculotendinous hamstring injury, with 6 injuries located proximally and 4 distally.

Failure was defined as recurrence of the same musculotendinous hamstring injury despite at least 3 months of conservative treatment. In the 3 months of this conservative protocol, all athletes had no less than a failed and retorn hamstring.

All surgeries were then performed by 2 senior orthopaedic surgeons (B.S-C., M.T.). Institutional review board approval was obtained for this study.

Surgical Technique

Proximal Lesions. The patient was placed in the prone position with a pillow under the hip to obtain slight hip flexion. Just prior to surgery, the scar tissue at the musculotendinous injury site was identified via sonography by a senior radiologist (J.C.), and a metallic anchor with metal suture (X-Reidy Breast Lesion Localization Needle; Cook Medical) was placed through the skin into the lesion (Figure 1). This served as a navigation beacon for our surgical dissection. A vertical 8-cm incision was made just under the gluteal fold. Dissection was carried down to the gluteal fascia, with care to avoid the posterior femoral cutaneous nerve, which crosses the hamstring from lateral-proximal to medial-distal and can cause hypoesthesia to the posterior thigh when damaged. Next, a transverse incision was made in the

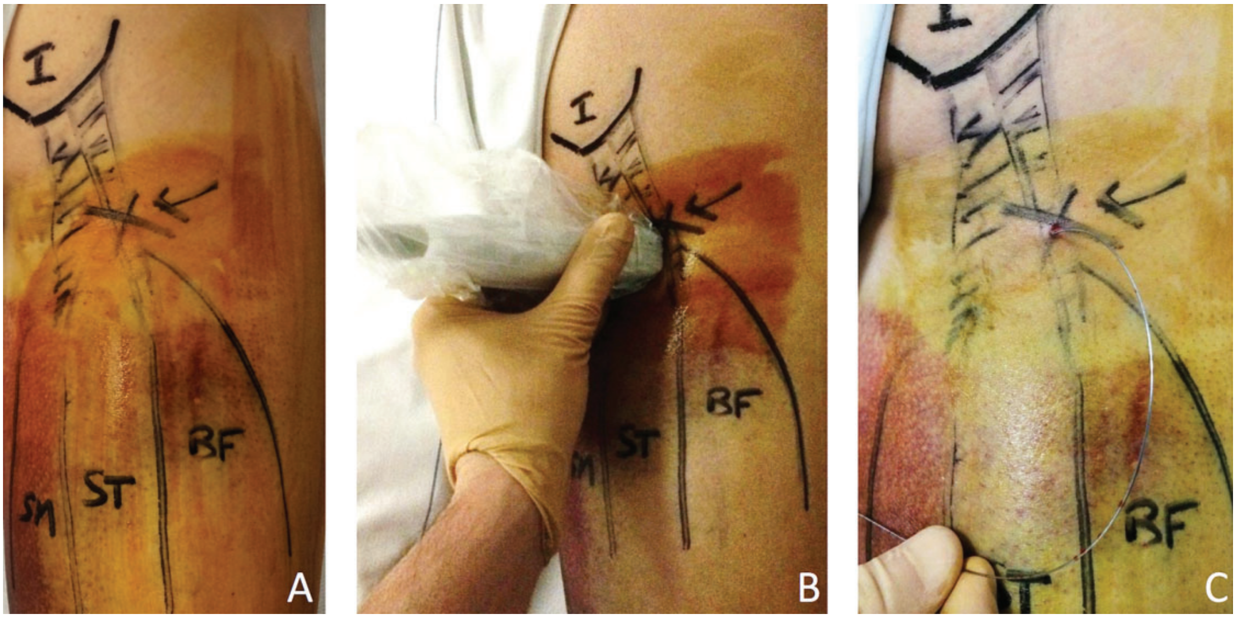

Figure 1. Injury site identification. (A) Skin marking of the different structures. (B) Ultrasound transducer placed at the muscle-tendon junction to locate the injury site. (C) Metallic anchor loaded with a metallic wire placed in the identified lesion site to serve as an Ariadne's thread for accurate surgical approach.

gluteal fascia at the inferior border of the gluteus maximus. The gluteus maximus was then elevated and retracted superiorly to expose the hamstring fascia. Care was taken not to place a retractor too deep on the ischium to minimize risk to the inferior gluteal nerve.

A longitudinal incision of the hamstring fascia was then made. This is the point at which the fibrous scar tissue and, occasionally, hematoma are encountered. The metallic anchor allows for precise localization of the scar tissue. The sciatic nerve is palpated in this plane and protected by lateral retraction of the tendons, keeping in mind that it passes in close proximity deep and lateral to the proximal hamstring origin.

Excision of the scar tissue, including the torn portion of the tendon, was then performed using a diathermy electrosurgical cautery pencil. The entire tendon stump was removed, leaving only the muscle belly. The belly of the remnant muscle was fixed with resorbable sutures (Vicryl USP 2; Ethicon) of approximately 4 cm without tension to the surrounding muscles in a side-to-side fashion (Figure 2). A suction drain was placed, and the wound then closed.

Distal Lesions. A different technique was performed for distal musculotendinous lesions of the semitendinosus. In these lesions, presurgical sonography was still performed, but no metallic anchor was placed. In all cases, the tendon was retracted proximally in the popliteus fold. The distal semitendinosus was located on sonography in the prone position and the skin marked. The tendon is superficial at this lesion location, so the use of a metallic anchor is not required. An incision was performed centered on the mark, and the tendon was easily exteriorized from its superficial location and removed using an open stripper (Figure 3).

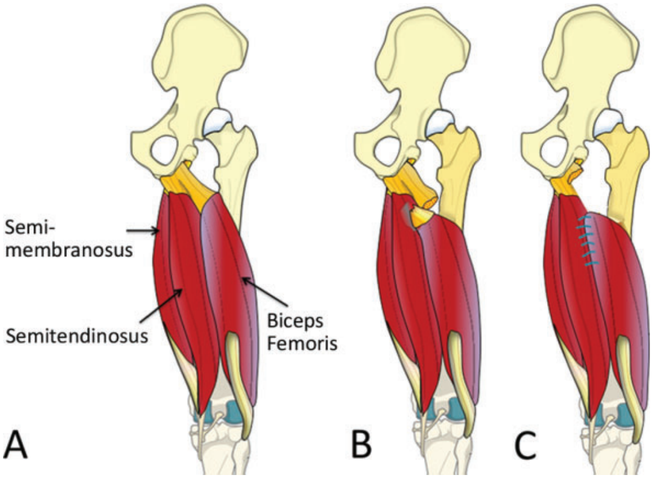

Figure 2. Proximal lesion. (A) Schematic representation of the hamstring muscles. (B) Proximal biceps femoris rupture at the muscle-tendon junction and subsequent scarring onto the semitendinosus muscle. (C) Excision of scar tissue and tension-free suturing of the belly remnant of the biceps femoris to the adjacent semitendinosus.

The incision was then closed after a suction device was placed. The drain was removed after 24 hours.

Postoperative Rehabilitation Protocol

Patients were mobilized 3 to 5 days after surgery and were on crutches for 2 weeks, with weightbearing as tolerated. Hip flexion in conjunction with knee extension was strictly

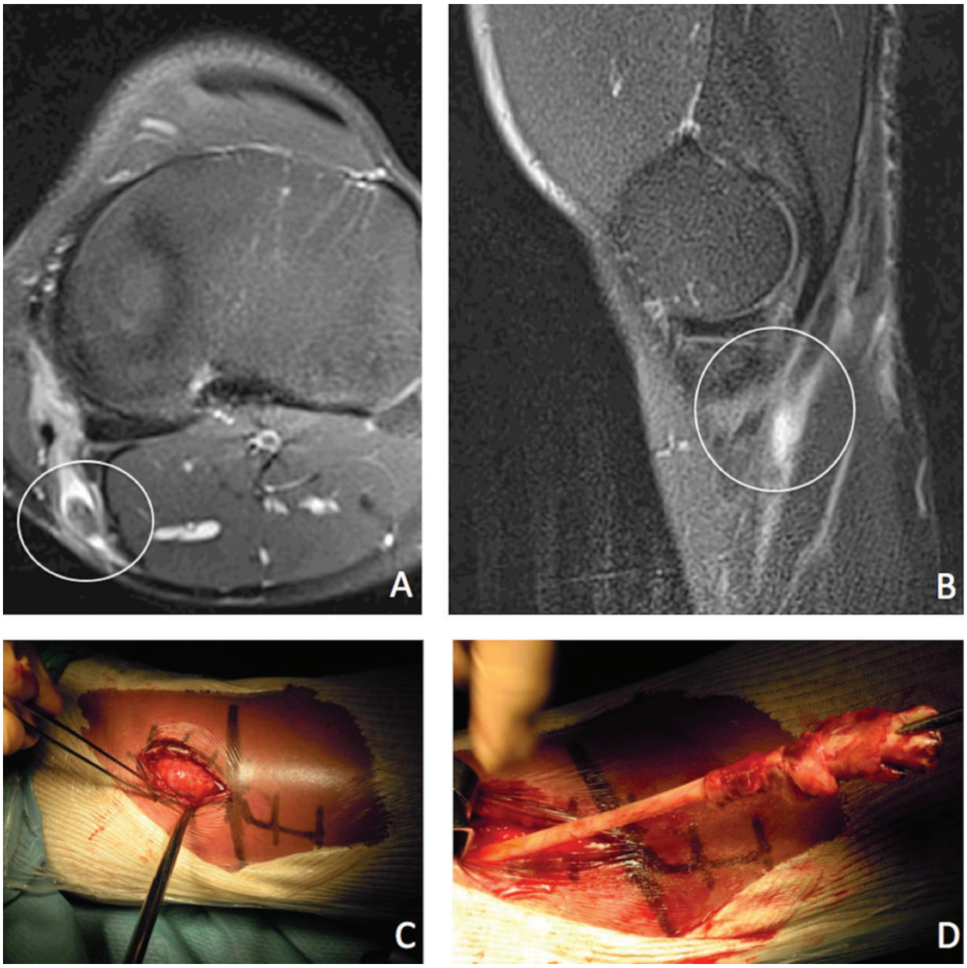

Figure 3. Distal lesion. (A) Coronal and (B) sagittal magnetic resonance images demonstrating distal avulsion of the semitendinosus. (C) Incision and identification of the tendon. (D) Stripping of the tendon.

forbidden; otherwise, range of motion was allowed as symptoms resolved, and no brace was used. Crutches were used for comfort until symptoms subsided. NSAIDs were used for postoperative pain management.

From weeks 2 to 6, a rehabilitation program was implemented based on progressive stretching of the hamstring group, with active and passive range of motion. From weeks 6 to 10, muscular strengthening was implemented and progressed as tolerated. At 2 months, sport-specific training was implemented, and return to play was allowed when the patient was pain free and completed sport-specific training. No isokinetic testing was performed.

Follow-up

All 10 patients were followed clinically until physician release for return to play. MRI scans were performed between 2 and 3 months postsurgery. At 3 months postoperatively, Lower Extremity Functional Scale (LEFS) and Marx activity scale scores were obtained.[5,28] The patients were then subsequently contacted for a phone interview by an independent investigator, with a mean follow-up of 28.5 months (range, 6-60 months). As part of the questionnaire, 2 specific questions were asked: (1) Have you had any recurrence of hamstring injury? (2) Can you confirm how many months were required for you to return to your previous level of play after surgery?

RESULTS

The mean player age at surgery was 25.2 years (range, 19-35 years). The musculotendinous hamstring lesions involved 8 semitendinosus and 2 biceps femoris, with 6 injuries located proximally and 4 distally. Conservative treatment lasted a mean 5.1 months (range, 3-9 months) after last recurrence, and patients had a mean 2.7 (range, 2-5) separate incidents of injury recurrence before surgical intervention was decided upon.

Of the 10 professional athletes undergoing surgical intervention, all returned to their preinjury level of play (Table 1). Neither significant abnormality nor remodeling of the muscle structure was observed on postoperative MRIs (Figure 4).

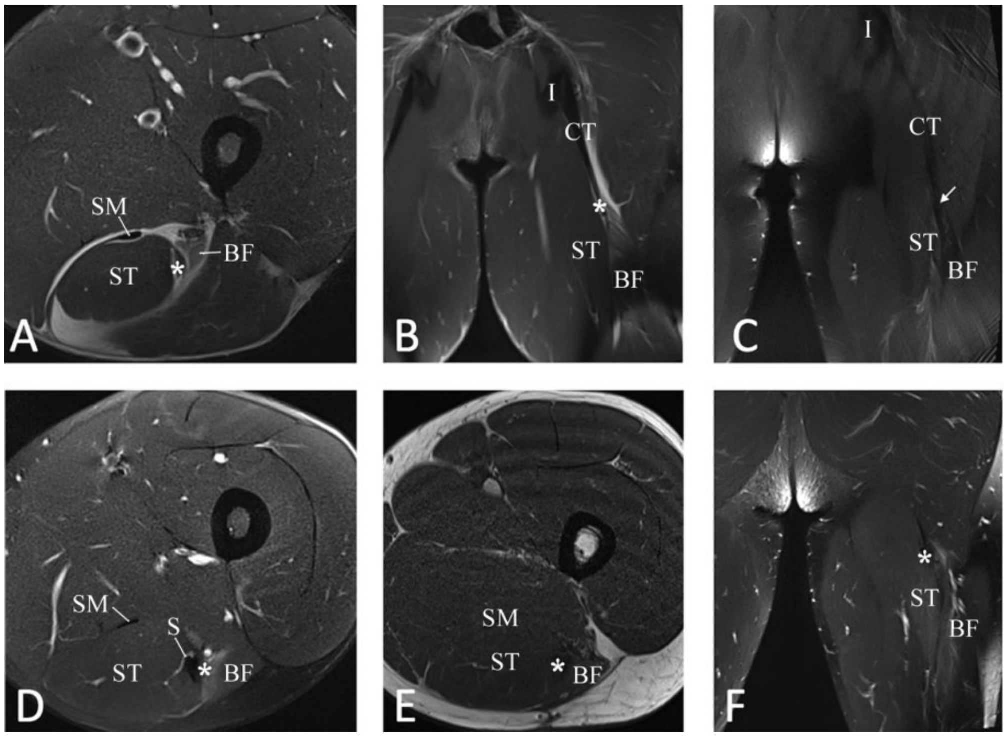

Figure 4. Magnetic resonance image illustration. (A) Transverse and (B) frontal proton density–weighted, fat-suppressed images of an initial proximal myotendinous injury (asterisk) of the biceps femoris. (C) Frontal proton density–weighted, fat-saturated image depicting a hypertrophic scar of the proximal muscle-tendon junction of the biceps femoris (arrow). (D) Transverse proton density–weighted, fat-suppressed image of an iterative injury of the biceps femoris (asterisk) with hypointense scarring of the myotendinous structure. (E) Transverse and (F) frontal proton density–weighted, fat-suppressed image demonstrating remodeling (asterisk) of the myotendinous unit 3 months after surgical treatment of a proximal biceps femoris myotendinous rupture. BF, biceps femoris; CT, common tendon; I, ischial tuberosity; S, scarring; SM, semimembranosus; ST, semitendinosus.

The mean amount of time from surgery to return to play was 3.4 months (range, 2-5 months). At 3 months postoperatively, 9 athletes had a Marx activity rating of 16 of a maximum of 16, and 1 had a 14. Additionally, 9 patients had an LEFS score of 80 of a maximum of 80, and 1 patient had a score of 78. There was no recurrence of injury reported by any of the athletes. In addition, no surgical complications were encountered (see Table 1).

DISCUSSION

Hamstring injuries can occur at either the proximal or distal "free" ends, the musculotendinous junctions, or at the central intramuscular tendon.[11,20,25,38] To our knowledge, this is the first study investigating the surgical treatment of recurrent musculotendinous injuries to the hamstring muscle group in professional athletes. Athletes in our study had excellent clinical outcome scores as defined by both the Marx activity rating score and LEFS score. Return to preinjury activity level is a commonly used outcome for treatment success,[6,19,21,22,39] and our results demonstrate 100% return to previous level of play after surgical intervention, with no recurrences or complications.

Professional athletes place especially high demand on the hamstring muscles, given the rapid acceleration and pivoting maneuvers inherent in their activities. The patients in our study were all professional athletes who had sustained multiple, recurrent hamstring injuries, some of which were potentially career ending. Hamstring injuries are common in this unique population and are a significant source of lost time.[2,12,13,16,40] With the exception of large, proximal avulsions, treatment for these athletes is initially conservative. Rehabilitation after injury consists of warm-up stretching, flexibility training, and eccentric muscle strength training,[31] known as "Nordic exercises."[32,36] These eccentric exercises are an instrumental component to any rehabilitation protocol but have demonstrated mixed results in the literature.[1,3,14,15] With completion of rehabilitation, most athletes can return to their previous level of play with good results.

However, despite the success of conservative rehabilitation in many of these patients, reinjury is still relatively common, occurring in between 12% and 31% of patients.[17,30,36,40] While there are many factors likely contributing to reinjury, including early return to play, incomplete rehabilitation, and the significant forces placed on the hamstring muscle group in this population,[9,10] it can also be secondary to insufficient healing of the musculotendinous junction.

When the injury occurs, a hematoma forms and scar tissue eventually develops. Over time, remodeling of the injured tissue occurs, but tendons heal at a prolonged rate and are relatively weak.[4,18] In addition, Pomeranz and Heidt[33] identified longer recovery times when the injury was in the musculotendinous junction. Furthermore, other studies have found that remodeling after injury predisposes to recurrence and prolonged healing times.[8,37] This is particularly true in musculotendinous tears, as tendon-to-muscle healing is often of poor quality and weak scar tissue is prone to recurrence.

Given the significant forces placed on the hamstring muscle group in this high-level population, the weakness and prolonged healing of the injury can place the professional athlete in jeopardy of recurrence.

Although the concept of removal of this remodeled musculotendinous structure is the same regardless of location, the surgical technique differs slightly. Proximally, the hamstring muscle group is a large musculotendinous structure; thus, removal of the degraded tissue is performed via a posterior approach, and subsequent suturing is performed connecting muscle to muscle. We believe it is important in this subset of patients to mark the lesions preoperatively using an imaging device to assist in directing the surgical dissection. For distal lesions, simply marking the lesion is adequate, as the dissection is more superficial and less complicated. Lempainen et al[23] previously reported a series of distal lesions of the hamstring myotendinous junction that were successfully treated using the same surgical protocol, including excision of the scar tissue and muscle stump suture. However, in their study, the series described did not include patients with recurrent lesions but instead included 18 patients with chronic pain and disability as a result of a single traumatic event that prevented them from resuming their sport at the same level. The elimination of fibrous scar tissue combined with intermuscular suturing allows for integral healing of muscle to muscle (see Figure 3). We believe this decreases the chances of reinjury by eliminating the remodeling tissue that is attempting to heal the musculotendinous defect. In addition, it allows the muscle to heal to the adjacent muscle in a tension-free manner, and thus, a stronger healing process will occur.

Ischiatic reinsertion of the distal stump is not feasible because the stump is located at the myotendinous junction, distant from the bony insertion. Repair using autograft or allograft has been proposed for chronic retracted proximal hamstring tears[27]; we did not choose this option given the delay required for return to play.

Our study has some weaknesses. We have no comparative group and few cases. Ideally, isokinetic testing would have been performed in these patients prior to the decision on return to play. In our series, this was not possible, given the vast geographic locations of these patients. Nevertheless, this is the first surgical option we are aware of for this injury in professional athletes. All patients suffered at least 2 recurrences of hamstring injury prior to surgery and then failed conservative treatment. Many of these athletes were facing career-ending circumstances due to recurrence of injury, and our treatment is the first to demonstrate successful surgical intervention without recurrence and with full return to play. In addition, all patients completed sport-specific training regimens and were asymptomatic prior to being released.

CONCLUSION

The surgical treatment of recurrent hamstring musculotendinous injury is a reliable and safe technique. Our results are encouraging, given that all of our patients returned to professional sports without surgical complication or recurrence after a mean follow-up of over 2 years. In cases of failed conservative treatment of musculotendinous hamstring lesions, surgical intervention may be a viable treatment option in professional athletes. Further investigation is needed to confirm these initial findings.

REFERENCES

1. Arnason A, Andersen TE, Holme I, Engebretsen L, Bahr R. Prevention of hamstring strains in elite soccer: an intervention study. *Scand J Med Sci Sports*. 2008;18:40-48.
2. Arnason A, Gudmundsson A, Dahl HA, Johannsson E. Soccer injuries in Iceland. *Scand J Med Sci Sports*. 1996;6:40-45.
3. Askling C, Karlsson J, Thorstensson A. Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. *Scand J Med Sci Sports*. 2003;13:244-250.
4. Askling C, Tengvar M, Saartok T, Thorstensson A. Acute first-time hamstring strains during high-speed running: a longitudinal study including clinical and magnetic resonance imaging findings. *Am J Sports Med*. 2007;35:197-206.
5. Binkley JM, Stratford PW, Lott SA, Riddle DL. The Lower Extremity Functional Scale (LEFS): scale development, measurement properties, and clinical application. North American Orthopaedic Rehabilitation Research Network. *Phys Ther*. 1999;79:371-383.
6. Birmingham P, Muller M, Wickiewicz T, Cavanaugh J, Rodeo S, Warren R. Functional outcome after repair of proximal hamstring avulsions. *J Bone Joint Surg Am*. 2011;93:1819-1826.
7. Cacchio A, Rompe JD, Furia JP, Susi P, Santili V, Paulis F. Shockwave therapy for the treatment of chronic proximal hamstring tendinopathy in professional athletes. *Am J Sports Med*. 2011;39:146-153.
8. Comin J, Malliaras P, Baquie P, Barbour T, Connell D. Return to competitive play after hamstring injuries involving disruption of the central tendon. *Am J Sports Med*. 2013;41:111-115.
9. Croisier JL. Factors associated with recurrent hamstring injuries. *Sports Med*. 2004;34:681-695.
10. Croisier JL, Forthomme B, Namurois M, Vanderthommen M, Creilaard JM. Hamstring muscle strain recurrence and strength performance disorders. *Am J Sports Med*. 2002;30:199-203.
11. De Smet AA, Best TM. MR imaging of the distribution and location of acute hamstring injuries in athletes. *AJR Am J Roentgenol*. 2000;174:393-399.
12. Ekstrand J, Hagglund M, Walden M. Injury incidence and injury patterns in professional football: the UEFA injury study. *Br J Sports Med*. 2011;45:553-558.
13. Ekstrand J, Timpka T, Hagglund M. Risk of injury in elite football played on artificial turf versus natural grass: a prospective two-cohort study. *Br J Sports Med*. 2006;40:975-980.
14. Engebretsen AH, Myklebust G, Holme I, Engebretsen L, Bahr R. Prevention of injuries among male soccer players: a prospective, randomized intervention study targeting players with previous injuries or reduced function. *Am J Sports Med*. 2008;36:1052-1060.

15. Gabbe BJ, Branson R, Bennell KL. A pilot randomized controlled trial of eccentric exercise to prevent hamstring injuries in community-level Australian football. *J Sci Med Sport*. 2006;9:103-109.
16. Hagglund M, Walden M, Ekstrand J. Previous injury as a risk factor for injury in elite football: a prospective study over two consecutive seasons. *Br J Sports Med*. 2006;40:767-772.
17. Heiser TM, Weber J, Sullivan G, Clare P, Jacobs RR. Prophylaxis and management of hamstring muscle injuries in intercollegiate football players. *Am J Sports Med*. 1984;12;368-370.
18. Kearney RS, Costa ML. Current concepts in the rehabilitation of an acute rupture of the tendon of Achilles. *J Bone Joint Surg Br*. 2012; 94:28-31.
19. Konan S, Haddad F. Successful return to high level sports following early surgical repair of complete tears of the proximal hamstring tendons. *Int Orthop*. 2010;34:119-123.
20. Kujala UM, Orava S, Järvinen M. Hamstring injuries: current trends in treatment and prevention. *Sports Med*. 1997; 23:397-404.
21. Lefevre N, Bohu Y, Naouri JF, Klouche S, Herman S. Returning to sports after surgical repair of acute proximal hamstring ruptures. *Knee Surg Sports Traumatol Arthrosc*. 2013;21:534-539.
22. Lempainen L, Sarimo J, Heikkila J, Mattila K, Orava S. Surgical treatment of partial tears of the proximal origin of the hamstring muscles. *Br J Sports Med*. 2006;40:688-691.
23. Lempainen L, Sarimo J, Mattila K, Heikkilä J, Orava S, Puddu G. Distal tears of the hamstring muscles: review of the literature and our results of surgical treatment. *Br J Sports Med*. 2007;41:80-83.
24. Levine WN, Bergfeld JA, Tesssendorf W, Moorman CT 3rd. Intramuscular corticosteroid injection for hamstring injuries. A 13-year experience in the National Football League. *Am J Sports Med*. 2000;28:297-300.
25. Malliaropoulos N, Papacostas E, Kiritsi O, Papalada A, Gougoulias N, Maffulli N. Posterior thigh muscle injuries in elite track and field athletes. *Am J Sports Med*. 2010;38:1813-1819.
26. Martin BF. The origins of the hamstring muscles. *J Anat*. 1968;102: 345-352.
27. Marx RG, Fives G, Chu SK, Daluiski A, Wolfe SW. Allograft reconstruction for symptomatic chronic complete proximal hamstring tendon avulsion. *Knee Surg Sports Traumatol Arthrosc*. 2009;17: 19-23.
28. Marx RG, Stump TJ, Jones EC, Wickiewicz TL, Warren RF. Development and evaluation of an activity rating scale for disorders of the knee. *Am J Sports Med*. 2001;29:213-218.
29. Mason DL, Dickens V, Vail A. Rehabilitation for hamstring injuries. *Cochrane Database Syst Rev*. 2012;12:CD004575.
30. Morris AF. *Sports Medicine: Prevention of Athletic Injuries*. Dubuque, IA: W.C. Brown; 1984.
31. Petersen J, Hölmich P. Evidence-based prevention of hamstring injuries in sport. *Br J Sports Med*. 2005;39:319-323.
32. Petersen J, Thorborg K, Nielsen MB, Budtz-Jørgensen E, Hölmich P. Preventive effect of eccentric training on acute hamstring injuries in men's soccer: a cluster-randomized controlled trial. *Am J Sports Med*. 2011;39:2296-2303.
33. Pomeranz SJ, Heidt RS Jr. MR Imaging in the prognostication of hamstring injury. *Radiology*. 1993;189:897-900.
34. Ropiak C, Bosco J. Hamstring Injuries. *Bull NYU Hosp Jt Dis*. 2012;70: 41-48.
35. Sarimo J, Lempainen L, Mattila K, Orava S. Complete proximal hamstring avulsions. *Am J Sports Med*. 2008;36:1110-1115.
36. Sherry MA, Best TM. A comparison of 2 rehabilitation programs in the treatment of acute hamstring strains. *J Orthop Sports Phys Ther*. 2004;34:116-125.
37. Silder A, Heiderscheit BC, Thelen DG, Enright T, Tuite MJ. MR observations of long-term musculotendon remodeling following a hamstring strain injury. *Skeletal Radiol*. 2008;37:1101-1109.
38. Slavotinek JP, Verrall GM, Fon GT. Hamstring injury in athletes: using MR imaging measurements to compare extent of muscle injury with amount of time lost from competition. *AJR Am J Roentgenol*. 2002; 179:1621-1628.
39. Wood DG, Packham I, Trikha SP, Linklater J. Avulsion of the proximal hamstring origin. *J Bone Joint Surg Am*. 2008;90:2365-2374.
40. Woods C, Hawkins RD, Maltby S, Hulse M, Thomas A, Hodson A. The Football Association Medical Research Programme: an audit of injuries in professional football–analysis of hamstring injuries. *Br J Sports Med*. 2004;38:36-41.