Ultrasound-Guided Cutting Wire Release of the Proximal Adductor Longus Tendon

A Feasibility Study

Brennan J. Boettcher,* DO, John H. Hollman,† PT, PhD, Michael J. Stuart,‡ MD, and Jonathan T. Finnoff,†§ DO

Investigation performed at the Mayo Clinic, Rochester, Minnesota, USA

Background: Adductor longus tendinopathy is a well-known etiology of chronic groin pain in elite athletes. Surgery is indicated for those who fail conservative treatment. No studies to date have evaluated the feasibility of an ultrasound-guided release of the proximal adductor longus tendon.

Purpose/Hypothesis: The primary aim of this study was to determine the feasibility of an ultrasound-guided selective adductor longus release with a cutting wire. A secondary aim was to determine safety by avoiding injury to adjacent structures. We hypothesized that the proximal adductor longus tendon can be released under ultrasound guidance with a cutting wire without injury to adjacent neurovascular or genitourinary structures.

Study Design: Descriptive laboratory study.

Methods: Ten adductor longus tendons (5 cadaveric specimens) from 4 males and 1 female between 76 and 89 years of age with a mean body mass index of 21.9 kg/m^2 (range, 16.8-29.6 kg/m^2) were used during this study. A single experienced physician sonographer performed ultrasound-guided proximal adductor longus tendon releases on all cadaveric specimens using a cutting wire. Dissection was performed by a second physician to determine the completeness of the tendon transections and to detect injury to adjacent neurovascular or genitourinary structures.

Results: All 10 adductor longus tendons were transected. Eight of 10 transections were complete, whereas in 2 transections, >99% of the tendon was transected. There were no injuries to adjacent genitourinary or neurovascular structures.

Conclusion: Ultrasound-guided adductor tendon release is feasible and safe in a cadaveric model. Further translational research should be performed to determine whether these results can be replicated in the clinical setting.

Clinical Relevance: Adductor longus tendinopathy frequently requires surgical intervention and prolonged time away from sport. The present study suggests that a selective adductor longus tendon release can be performed with ultrasound guidance. This procedure warrants further translational research to explore its use in clinical practice.

Keywords: groin pain; tendinosis; ultrasound guidance; adductor longus

Groin pain occurs in 5% to 18% of the general sporting population, most frequently in sports such as ice hockey and those that involve kicking (eg, soccer/football, Australian football, rugby).[23,26] While sports hernia and athletic pubalgia are 2 terms commonly utilized generically to describe groin pain in athletes, the Doha meeting in 2015 established recommendations for terminology to describe groin pain in athletes, notably by classifying its etiology.[26] Among the classifications, 1 well-recognized etiology is adductor-related groin pain, which can occur in the adductor longus (AL) tendon or the AL/rectus abdominis aponeurosis.

Nonoperative treatment for proximal AL tendon or AL/rectus abdominis aponeurosis injuries includes activity modification, compression shorts, physical therapy, physical modalities, manual therapy, medications, and injections, but these interventions frequently fail in the elite athlete.[13,15,24] The success of physical therapy with and without an active training program ranges from 11.7% to 78.6%, and corticosteroids may be helpful in 67% of athletes, although the data on the success of these nonoperative treatments are somewhat limited.[11,12,27] For those who fail nonoperative intervention, surgery typically results in favorable clinical outcomes.[2,4,6,9,16-21,25] Surgical treatment for AL tendon pathology involves an open or percutaneous

The Orthopaedic Journal of Sports Medicine, 7(8), 2325967119866010
DOI: 10.1177/2325967119866010

AL release. This can be performed in isolation or with AL/rectus abdominis aponeurosis repair or debridement or hernia repair, which sometimes involves mesh placement. AL releases are currently performed with standard surgical techniques that require an incision, dissection down to the target structure, and release of the AL tendon. Given the amount of tissue disruption during the surgical procedure, the athlete is frequently not allowed to return to full unrestricted activity until 4 to 18.5 weeks after the procedure.[2,3,16-18,20] Furthermore, surgical AL releases may result in complications, including adductor weakness, hematoma formation, infection, numbness, painful scarring, contracture, dysuria, and painful intercourse.[2,3,5,16,19,23] Thus, identifying the least invasive means by which to release the tendon to minimize risk and facilitate rapid return to sport is desirable.

The past several decades have seen significant advances in ultrasound-guided (USG) procedures. Ultrasound has progressed from a means of guiding injections into joints, bursae, and tendon sheaths to guiding more advanced procedures with needles (eg, needle tenotomies) and finally to performing USG surgical procedures (eg, carpal tunnel releases, fasciotomies, ultrasonic tendon debridement, long head of the biceps tendon releases).[1,7,10,14,22] These procedures offer many possible advantages over standard surgical procedures, including lower cost, quicker recovery, low rate of complications, and increased patient satisfaction. As ultrasound technology continues to improve and more musculoskeletal providers adopt the technology, there is interest in expanding the number of USG surgical procedures available to patients.

Guo et al[7,8] developed a USG carpal tunnel release technique to place a medical-grade cutting wire around the transverse carpal ligament. The wire is then pulled in a back-and-forth sawing motion, similar to a Gigli saw, to transect the transverse carpal ligament and release the carpal tunnel. We hypothesized that this technique could be adapted to perform other USG surgical procedures.

The primary aim of this study was to determine if the proximal AL tendon could be released with ultrasound guidance and a cutting wire. Secondary aims included assessing the completeness of the AL tendon release, injury to the AL muscle and adjacent neurovascular and genitourinary structures, technical difficulty of the procedure, and duration of time to perform the procedure. We hypothesized that USG proximal AL releases would be relatively easy to perform, take less than 5 minutes, result in a complete release of the proximal AL tendon, and not be associated with damage to adjacent structures. If successful, these findings could be used as the foundation for research translating this technique into clinical practice.

METHODS

Design

One operator with 12 years of USG procedural experience (J.T.F.) performed all AL tendon releases. Five unembalmed cadaveric specimens (10 AL tendons) were utilized. A separate investigator (B.J.B.), not involved in performing the procedures, dissected each AL tendon to assess the outcome measures (see Outcome Measures section). All procedures were performed in our institution's Procedural Skills Laboratory. All cadavers were free from visible trauma or evidence of prior surgery in the pelvis, hip, or adductor region. The cadaveric specimens were donated to our institution's anatomic bequest program, and the study received institutional board approval.

Equipment

The procedures were performed with the following equipment:

- Samsung RS-80 ultrasound machine and L15-7io linear array probe
- 18-gauge, 3.5-inch Tuohy needles (Epimed International Inc)
- Guo Percutaneous Wire (Ridge & Crest Company)

Adductor Tendon Release Protocol

The lower body specimens were placed supine in a frog-leg position on the table. The proximal medial thigh was evaluated sonographically in short and long axis to identify the AL, adductor brevis, adductor magnus, pectineus, gracilis, femoral neurovascular structures, obturator neurovascular structures, and, in males, the spermatic cord. The location of the AL tendon release (approximately 3 cm distal to the AL origin) and optimal anterolateral-to-posteromedial needle path were determined. The needle entry and exit sites were marked on the skin with an indelible marker.

An 18-gauge, 3.5-inch Tuohy needle was bent to create a curve, with the concavity of the curve facing toward the bevel of the needle (Figure 1). The needle was then attached to a 10-mL syringe filled with water. The needle was

§Address correspondence to Jonathan T. Finnoff, DO, Mayo Clinic Sports Medicine Center, 600 Hennepin Ave, #310, Minneapolis, MN 55403, USA (email: finnoff.jonathan@mayo.edu).
*Summit Orthopedics, Sports Medicine, Eagan, Minnesota, USA.
†Department of Physical Medicine and Rehabilitation, Mayo Clinic College of Medicine and Science, Rochester, Minnesota, USA.
‡Department of Orthopedic Surgery, Mayo Clinic College of Medicine and Science, Rochester, Minnesota, USA.
One or more of the authors has declared the following potential conflict of interest or source of funding: Funding for this project was provided by a grant from the Mayo Clinic Department of Physical Medicine and Rehabilitation Research Committee. M.J.S. has received research funding from Arthrex, Stryker, and the USA Hockey Foundation and consulting fees and royalties from Arthrex. J.T.F. serves on the medical advisory board for AIM Specialty Health, COVR Medical, and Sanofi and receives royalties from Demos Publishing and Up to Date. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.
Ethical approval for this study was obtained from the Biospecimens Subcommittee of the Mayo Clinic Institutional Review Board (No. 17-011054 Bio00015935).

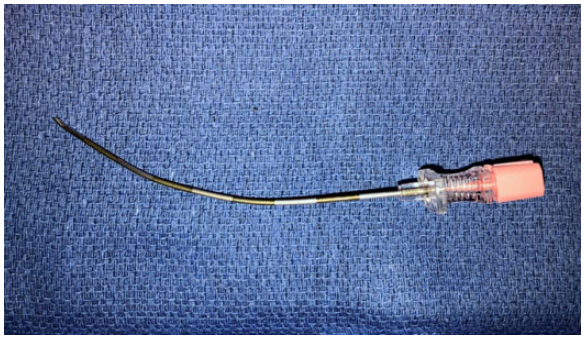

Figure 1. An 18-gauge, 3.5-inch Tuohy needle bent to create a curve, with the concavity of the bend facing the bevel of the needle.

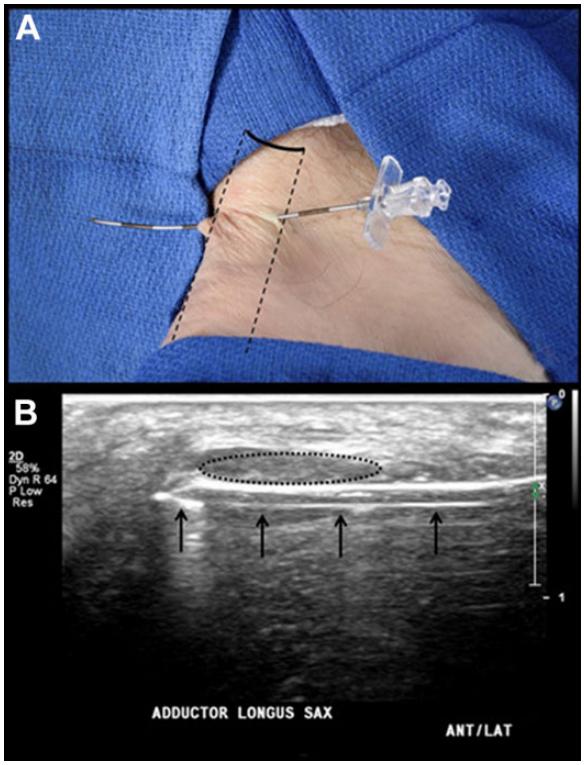

Figure 2. (A) A left cadaver groin with 18-gauge Tuohy needle placed deep to the adductor longus tendon but superficial to the adductor longus muscle. Top, proximal; bottom, distal; right, lateral; left, medial. Dashed line, outline of the adductor longus tendon; solid curved line, pubic tubercle. (B) Ultrasound image of 18-gauge Tuohy needle deep to the left adductor longus tendon but superficial to the adductor longus muscle. Dotted oval, outline of adductor longus tendon superficial to the needle; arrows, Tuohy needle. ANT/LAT, anterior/lateral; SAX, short axis.

introduced through the needle entry mark on the skin. The needle was guided long-axis relative to the transducer, in an anterolateral-to-posteromedial direction in a tissue plane between the deep portion of the AL tendon and the superficial portion of the AL muscle (Figure 2). Water was

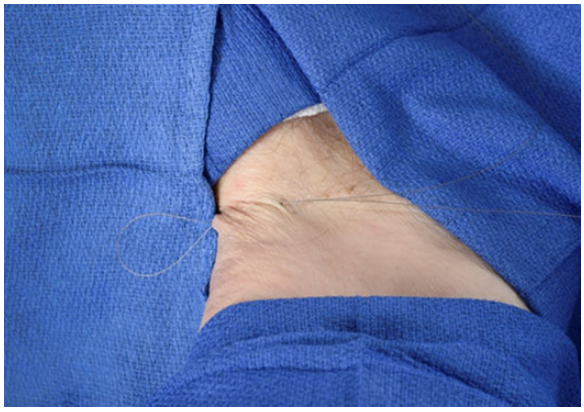

Figure 3. Left adductor longus tendon with the cutting wire entering and exiting the skin after it has been placed around the tendon. Top, proximal; bottom, distal; right, lateral; left, medial.

injected through the needle as it was advanced to hydrodissect a tissue plane between the AL muscle and tendon and reduce the chance of inadvertently injuring adjacent structures. The needle was advanced until it exited through the needle exit mark on the skin.

A cutting wire was threaded through the hub of the Tuohy needle and advanced until the end of the cutting wire exited through the tip of the needle such that a portion of the cutting wire extended out of both ends of the needle. The portion of the wire extending out of the needle tip was held in place while the needle was withdrawn from the cadaveric specimen. Thus, the wire was left in the specimen between the AL tendon and muscle, with one end exiting the skin at the needle entry site and the other end exiting the skin at the needle exit site.

The same Tuohy needle was reintroduced through the needle entry mark on the anterolateral aspect of the skin and guided in a long-axis relative to the transducer between the superficial aspect of the AL tendon and overlying subcutaneous tissue and out through the needle exit mark on the skin. Care was taken to stay immediately adjacent to the wire at the needle entry and exit sites on the skin. Water was injected while the needle was advanced to hydrodissect a tissue plane between the subcutaneous tissue and the superficial aspect of the AL tendon.

The cutting wire, which protruded through the needle exit mark, was then threaded back through the tip of the Tuohy needle until a portion of the cutting wire exited through the needle hub. The Tuohy needle was then withdrawn from the cadaveric specimen, leaving a loop of cutting wire around the AL tendon, with both ends of the wire exiting the skin at the location of the needle entry sites (Figure 3).

The ultrasound transducer was then used to image the cutting wire, tendons, adjacent musculature, and relevant neurovascular structures to ensure that the cutting wire circumscribed only the AL tendon and no other significant structures (Figure 4). Two 6-mL syringes were then obtained and their plungers withdrawn to the 2-mL mark.

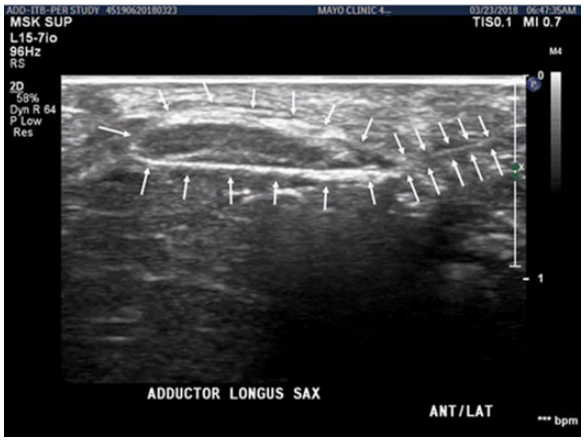

Figure 4. Ultrasound image of a left adductor longus tendon with the cutting wire (white arrows) approaching from the anterolateral aspect of the tendon (right of image), circling around the adductor longus tendon, and exiting immediately adjacent to the entry wire. The location where the wires enter and exit the skin is located on the right side of the screen. As they travel to the adductor longus tendon, the entering and exiting wires are immediately adjacent (indistinguishable in this image). ANT/LAT, anterior/lateral; SAX, short axis.

Approximately 2 cm of the cutting wire ends were threaded into the end of each syringe (1 wire per syringe) and secured in place with a female-to-female Luer-Lok adapter (Figure 5A). The syringes were used as handles, and, by pulling on the syringes, a traction force was placed through the cutting wire. The cutting wire was then pulled back and forth, keeping the syringes close together to prevent cutting of the skin, until the cutting wire transected the AL tendon and pulled through the needle entry site of the skin (Figure 5B).

Outcome Measures

After the AL tendon was released, a separate investigator dissected the cadaveric specimen and evaluated it for the following outcome measures:

- Presence of a cut in the skin at the needle entry or exit site
- The width of the tendon and the width of the tendon transection (both in millimeters)
- The presence and extent of AL muscle fiber transection deep to the tendon (0, no damage; 1, <10% AL muscle cut; 2, 10%-30% AL muscle cut; 3, >30% AL muscle cut; 4, complete AL muscle transection)
- Damage to adjacent structures
- Difficulty of the procedure (0, no difficulty; 10, most difficult procedure possible)
- Duration of time to complete the procedure

Statistics

Descriptive statistics, including means and ranges, were used to analyze the data.

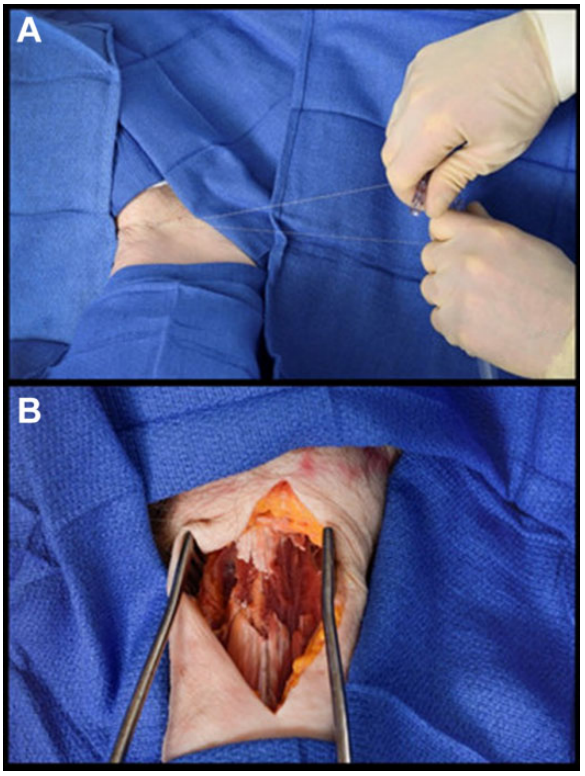

Figure 5. (A) Left adductor longus tendon being transected via a sawing motion with the cutting wire. Note that the wire is both entering and exiting the skin through the same needle entry sites on the anterolateral (right) side of the tendon. The "looped" slack in the wire shown in Figure 3 has been taken up, and the wire now intimately surrounds only the adductor longus tendon, as seen in the ultrasound image in Figure 4. (B) A completely transected left adductor longus tendon. Top, proximal; bottom, distal; right, lateral; left, medial.

RESULTS

The 5 unembalmed cadavers with bilateral lower limbs (ie, 10 lower limbs) were free of visible trauma to the hip or groin region. There were 4 males and 1 female, with a mean age of 83.6 years (range, 76-89 years) and body mass index of 21.9 kg/m^2 (range, 16.8-29.6 kg/m^2). One cadaver had a below-knee amputation (see Discussion for details). Table 1 presents a summary of the results. All 10 AL tendons in the 5 cadaveric specimens were cut. Eight of the tendons were completely transected (Figure 5B), with the remaining 2 tendons having only a few intact tendon fibers that interdigitated with the AL muscle deep to the tendon. The transection occurred an average of 3.0 cm from the pubic tubercle (range, 1.5-4 cm). The mean width of the AL tendon was 1.6 cm (range, 1.0-2.5 cm). The mean width of the tendon transection was 1.6 cm (range, 1.0-2.5 cm).

No damage occurred to the AL muscle fibers deep to the tendon in all 5 cadaveric specimens (ie, 10 procedures). The amount of muscle involvement was grade 1 in 4 cadaveric specimens and grade 2 in 1. The procedure took a mean of 4 minutes 21 seconds to complete (range, 3 minutes 30

TABLE 1
Postprocedure Analysis of Completeness of AL Tendon Release and Evaluation of Adjacent Structures for Damage, Time to Complete Procedure, and Operator-Rated Procedural Difficulty[a]

Cadaver: Side	Distance From PT, cm	Tendon Width, cm	Width of Cut, cm	Percentage of Tendon Cut	Muscle Damage, 0-4[b,c]	Operator Rating of Difficulty, 0-10	Time, min
1							
Right	1.5	1.8	1.8	100	0	3	6
Left	2.5	1	1	100	1	2	4
2							
Right	3.5	1.7	1.7	100	1	2	4.5
Left	2.4	1.8	1.8	>99[d]	0	2	3.5
3							
Right	2	1	1	100	0	2	4
Left	3.3	1.1	1.1	>99[d]	0	2	3.5
4							
Right	3.4	1.4	1.4	100	1	2	4.5
Left	3.5	2	2	100	0	2	4
5							
Right	3.5	2.5	2.5	100	2	4	5.5
Left	4	1.3	1.3	100	1	4	4
Mean	2.96	1.43	1.43		0.6	2.5	4.35

[a]In all cases, the tendon was cut, and the skin was not cut. AL, adductor longus; PT, pubic tubercle.
[b]Grading scale: 0, trace (scrapes on muscle); 1, minimal muscle cut (<10%); 2, moderate muscle cut (10%-30%); 3, major muscle cut (>30%); 4, complete transection of muscle.
[c]None of the adjacent structures were damaged, with the exception of cadaver 5. In this case, the right tendon was undulating on the deep surface, so it had to include some muscle to be cut. The right tendon was also more lateral in muscle versus the rest of the cadavers. Note that cadaver 5 also had a below-knee amputation.
[d]One fiber intact deep.

seconds–6 minutes), and the mean difficulty of the procedure was rated at 2.5 out of 10 (range, 2-4). No specimens had a cut in the skin at either the needle entry or exit site, and no damage occurred to adjacent structures.

DISCUSSION

The primary purpose of this study was to assess the feasibility of performing a USG AL tendon release with a cutting wire. To the best of our knowledge, this is the first study to assess a USG technique for releasing the proximal AL tendon. The results of this study suggest that in a cadaveric model, this procedure is safe (no clinically relevant muscle or adjacent neurovascular, musculoskeletal, or genitourinary injuries were identified) and results in the complete or near-complete transection of the AL tendon while avoiding a surgical incision in the groin, which will likely lead to fewer complications and a faster recovery. This procedure has the added advantage of potentially being performed in the clinic setting, under local anesthesia, which increases patient convenience and decreases costs.

All 5 cadaveric specimens achieved complete or near-complete release of the AL tendon without significant damage to the underlying muscle. In the 2 cadaveric specimens where near-complete AL tendon releases were achieved, only a few tendon fibers were left intact. It is likely that these would provide minimal restriction to hip abduction and/or would lyse with adductor stretching. Therefore, these would probably function similarly to a complete AL tendon release. The findings of our study suggest that a USG AL tendon release with a cutting wire can reliably release the AL tendon near its origin from the pubic tubercle. As such, this procedure has potential clinical applicability to individuals with chronic, recalcitrant AL tendinopathy or individuals with adductor contractures and spasticity.

Of note, 1 cadaver had a below-knee amputation on the right side. The side of the amputation displayed an enlarged AL tendon with an undulating deep surface, which made complete transection of the deep fibers of the AL tendon difficult without extending into the AL muscle. This specimen had 1 small tendon fiber intact, and between 10% and 30% of the AL muscle belly was cut in the area of the tendinous undulations into the adjacent AL muscle. It is unclear whether the below-knee amputation contributed to the morphologic changes identified in this cadaver, but there were side-to-side asymmetries in the AL tendon morphology in this cadaveric specimen. Furthermore, the amount of AL muscle cut deep to the tendon was of unknown clinical significance and represented only a very small percentage of the muscle.

Only 1 other study has investigated a "nonopen" AL release technique. El Hage et al[4] performed percutaneous releases of the proximal AL. They released the tendon completely in 46 patients, and >75% of the tendon was released in the remaining 4 patients. They also cut a mean 83.7% of the adjacent AL muscle, and in 14% of the cases, the adductor brevis muscle was also partially transected. While they reported no neurovascular complications, the anterior branch of the obturator nerve runs between the AL and

adductor brevis. Thus, this nerve was at risk with the percutaneous AL release technique. As compared with our technique, the percutaneous technique evaluated by El Hage et al resulted in a lower percentage of complete AL tendon transections (75% vs 80%); a larger amount of damage to the adjacent AL muscle, which may result in a larger amount of bleeding; and injury to the adjacent adductor brevis muscle, which increases the risk of not only bleeding but also injuring the obturator neurovascular structures, as they course between the AL and adductor brevis muscles.

Several limitations to our study must be acknowledged. First, only 10 procedures were included in this investigation. Therefore, future studies with larger numbers of cadaveric specimens are required to confirm our preliminary findings. The cadaveric specimens included in this study were also relatively thin. Future studies that include specimens or individuals with a larger body habitus should be performed. Only 1 of the cadaveric specimens was female. Additionally, tendinopathy in the AL tendon is frequently encountered in an age demographic much younger than that of our specimens. The ultrasound features of tendinopathy, thickening and hypoechogenicity, may make it more difficult to identify the borders of the tendon than experienced in this cadaveric study. We believe that this is unlikely to change the accuracy, given that most procedures performed on tendons under ultrasound guidance are on tendinopathic tendons. Thus, future research should include a larger cohort that includes (1) cadaveric specimens of younger age and female sex, to see if the success rates differ in either, and (2) specimens with tendinopathy.

Additionally, the procedures were subject to all of the limitations associated with a cadaveric model, including inability to completely assess potential complications such as bleeding, infection, or functionally incomplete release. Furthermore, while it is hypothesized that this technique will result in lower cost and faster recovery, these cannot be assessed in a cadaveric model. Return to sport following a standard isolated AL release is reportedly between 11 and 18.5 weeks or 4 to 16 weeks when combined with a hernia repair.[2,3,16-18,20] Complications associated with standard AL releases include adductor weakness, hematoma formation, infection, numbness, painful scarring, contracture, dysuria, and painful intercourse.[3,16,17,19,20] One disadvantage of a USG AL tendon release is the inability to perform electrocautery hemostasis, as can be performed during an open surgical procedure. This may result in more bleeding following a USG AL tendon release as compared with an open surgical procedure. Fortunately, the procedure investigated in this study demonstrated minimal trauma to adjacent muscle, thus minimizing the risk of bleeding. Furthermore, the AL tendon is very superficial, making it amenable to postprocedure hemostasis via direct compression and ice. The addition of epinephrine to the local anesthetic used for the procedure may also decrease the risk of hematoma formation.

All procedures were performed by a physician with extensive experience performing USG surgery. Of note, while not specifically investigated in this study, this procedure was performed successfully in the procedural skills laboratory several times by a sports medicine fellow while developing the technique, with similar success rates, suggesting that it may be successfully performed by physicians with less USG procedural experience. However, further research is required to determine whether physicians with different levels of USG procedural experience are able to reproduce these results.

CONCLUSION

This cadaveric study suggests that USG AL tendon release with a cutting wire is not very difficult, takes less than 5 minutes to perform, successfully transects the AL tendon, results in minimal muscle damage, and does not injure adjacent structures. Future translational research is warranted to investigate the safety, efficacy, and cost-effectiveness of this technique in the clinical setting.

ACKNOWLEDGMENT

The authors thank Dr Brittany Moore for equipment and technical and setup assistance while performing the procedures, the staff at the Mayo Clinic Procedural Skills Laboratory, and the generosity of the donors, whose noble gift made this study possible.

REFERENCES

1. Aly AR, Rajasekaran S, Mohamed A, Beavis C, Obaid H. Feasibility of ultrasound-guided percutaneous tenotomy of the long head of the biceps tendon—a pilot cadaveric study. *J Clin Ultrasound*. 2015; 43(6):361-366.
2. Atkinson HDE, Johal P, Falworth MS, Ranawat VS, Dala-Ali B, Martin DK. Adductor tenotomy: its role in the management of sports-related chronic groin pain. *Arch Orthop Trauma Surg*. 2010;130(8):965-970.
3. de Queiroz RD, de Carvalho RT, de Queiroz Szeles PR, Janovsky C, Cohen M. Return to sport after surgical treatment for pubalgia among professional soccer players. *Rev Bras Ortop*. 2014;49(3):233-239.
4. El Hage S, Rachkidi R, Noun Z, et al. Is percutaneous adductor tenotomy as effective and safe as the open procedure? *J Pediatr Orthop*. 2010;30(5):485-488.
5. Garvey JF, Hazard H. Sports hernia or groin disruption injury? Chronic athletic groin pain: a retrospective study of 100 patients with long-term follow-up. *Hernia*. 2014;18(6):815-823.
6. Gill TJ, Carroll KM, Makani A, Wall AJ, Dumont GD, Cohn RM. Surgical technique for treatment of recalcitrant adductor longus tendinopathy. *Arthrosc Tech*. 2014;3(2):e293-e297.
7. Guo D, Guo D, Guo J, Malone DG, Wei N, McCool LC. A cadaveric study for the improvement of thread carpal tunnel release. *J Hand Surg Am*. 2016;41(10):e351-e357.
8. Guo D, Tang Y, Ji Y, Sun T, Guo J, Guo D. A non-scalpel technique for minimally invasive surgery: percutaneously looped thread transection of the transverse carpal ligament. *Hand (N Y)*. 2015;10(1):40-48.
9. Harr JN, Brody F. Sports hernia repair with adductor tenotomy. *Hernia*. 2017;21(1):139-147.
10. Henning PT, Yang L, Awan T, Lueders D, Pourcho AM. Minimally invasive ultrasound-guided carpal tunnel release: preliminary clinical results. *J Ultrasound Med*. 2018;37(11):2699-2706.
11. Holmich P, Uhrskou P, Ulnits L, et al. Effectiveness of active physical training as treatment for long-standing adductor-related groin pain in athletes: randomised trial. *Lancet*. 1999;353(9151):439-443.
12. Jose J, Buller LT, Fokin A Jr, Wodicka R, Subhawong T, Lesniak B. Ultrasound-guided corticosteroid injection for the treatment of

athletic pubalgia: a series of 12 cases. *J Med Ultrasound*. 2015;23(2): 71-75.
13. Kraeutler MJ, Garabekyan T, Mei-Dan O. The use of platelet-rich plasma to augment conservative and surgical treatment of hip and pelvic disorders. *Muscles Ligaments Tendons J*. 2016;6(3): 410-419.
14. Lueders DR, Sellon JL, Smith J, Finnoff JT. Ultrasound-guided fasciotomy for chronic exertional compartment syndrome: a cadaveric investigation. *PM R*. 2017;9(7):683-690.
15. Lynch TS, Bedi A, Larson CM. Athletic hip injuries. *J Am Acad Orthop Surg*. 2017;25(4):269-279.
16. Maffulli N, Loppini M, Longo UG, Denaro V. Bilateral mini-invasive adductor tenotomy for the management of chronic unilateral adductor longus tendinopathy in athletes. *Am J Sports Med*. 2012;40(8): 1880-1886.
17. Mei-Dan O, Lopez V, Carmont MR, et al. Adductor tenotomy as a treatment for groin pain in professional soccer players. *Orthopedics*. 2013;36(9):e1189-e1197.
18. Messaoudi N, Jans C, Pauli S, Van Riet R, Declercq G, Van Cleemput M. Surgical management of sportsman's hernia in professional soccer players. *Orthopedics*. 2012;35(9):e1371-e1375.
19. Robertson IJ, Curran C, McCaffrey N, Shields CJ, McEntee GP. Adductor tenotomy in the management of groin pain in athletes. *Int J Sports Med*. 2011;32(1):45-48.
20. Rossidis G, Perry A, Abbas H, et al. Laparoscopic hernia repair with adductor tenotomy for athletic pubalgia: an established procedure for an obscure entity. *Surg Endosc*. 2015;29(2):381-386.
21. Schilders E, Dimitrakopoulou A, Cooke M, Bismil Q, Cooke C. Effectiveness of a selective partial adductor release for chronic adductor-related groin pain in professional athletes. *Am J Sports Med*. 2013; 41(3):603-607.
22. Seng C, Mohan PC, Koh SB, et al. Ultrasonic percutaneous tenotomy for recalcitrant lateral elbow tendinopathy: sustainability and sonographic progression at 3 years. *Am J Sports Med*. 2016;44(2): 504-510.
23. Serner A, van Eijck CH, Beumer BR, Holmich P, Weir A, de Vos RJ. Study quality on groin injury management remains low: a systematic review on treatment of groin pain in athletes. *Br J Sports Med*. 2015; 49(12):813.
24. Topol GA, Reeves KD, Hassanein KM. Efficacy of dextrose prolotherapy in elite male kicking-sport athletes with chronic groin pain. *Arch Phys Med Rehabil*. 2005;86(4):697-702.
25. Van Der Donckt K, Steenbrugge F, Van Den Abbeele K, Verdonk R, Verhelst M. Bassini's hernial repair and adductor longus tenotomy in the treatment of chronic groin pain in athletes. *Acta Orthop Belg*. 2003;69(1):35-41.
26. Weir A, Brukner P, Delahunt E, et al. Doha agreement meeting on terminology and definitions in groin pain in athletes. *Br J Sports Med*. 2015;49(12):768-774.
27. Yousefzadeh A, Shadmehr A, Olyaei GR, Naseri N, Khazaeipour Z. Effect of Holmich protocol exercise therapy on long-standing adductor-related groin pain in athletes: an objective evaluation. *BMJ Open Sport Exerc Med*. 2018;4(1):e000343.