Abductor Hallucis: Anatomical Variation and Its Clinical Implications in the Reconstruction of Chronic Nonhealing Ulcers and Defects of Foot

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Abductor hallucis (AH) is an intrinsic muscle of sole of the foot. It is commonly used in the coverage of ankle and heel defects and chronic nonhealing ulcers of the foot; its use is reported to have a favorable long-term outcome. The muscle's apt bulk and size, its simple surgical isolation, absence of donor-site defect, unvaried anatomy, and long neurovascular pedicle are some of the advantages that make it a promising muscle flap. During routine cadaver dissection in the Department of Anatomy of Jawaharlal Institute of Postgraduate Medical Education and Research (JIPMER), Pondicherry, India, we identified an anatomical variation in AH in both feet of a 45-year-old embalmed male Indian cadaver. The variant muscle had innumerable proximal attachments, a majority of them arising atypically in the form of tough tendinous slips from the medial intermuscular septum at the junction of central and tibial components of plantar aponeurosis, the medial surface of first metatarsal and the intermuscular septum separating AH from the flexor hallucis brevis. The tendon: muscle ratio was 1.76 , higher than the normal reported ratio of 0.56 ± 0.07 . This article highlights the variation noted and its implication for clinicians. On Internet search, we did not come across the variations described in our article. Findings of the anatomical variation reported in this article could benefit surgeons who decide to use AH flaps in the future.

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Submitted for publication November 20, 2014. Accepted in revised form February 9, 2015.

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INTRODUCTION

ABDUCTOR HALLUCIS (AH) is the most superficial muscle in the medial compartment of the first layer of sole of the foot. Proximally, the muscle is attached predominantly to the flexor retinaculum and posterior calcaneal tuberosity, with a few fibers of attachment to the intermuscular septum between it and the flexor hallucis brevis. Its tendon is attached distally to the base of the proximal phalanx of the hallux. The muscle is innervated by a branch of the medial plantar nerve and supplied by a branch of the medial plantar artery. The AH has a role in maintaining the medial longitudinal arch of the foot

and its contraction causes abduction of the hallux.¹

In reconstructive surgery, AH is used as a local flap to cover the ankle and foot defects and as a free flap for thenar defects and in reanimation of the cheek in facial palsy. In pediatric surgery, AH is a muscle of interest in procedures dealing with various congenital deformities of the foot such as hallux valgus.² In microvascular surgery, this muscle is an important alternative to other methods of reconstruction, as it can be used conveniently as a pedicled flap.² It is reportedly used in electromyographic evaluation of the recovery of lower limb musculature in patients following spinal cord injury.³

Any deviation from the normal anatomy may affect the clinicians while using this muscle for the various indications mentioned above. This article highlights the variation noted during a routine cadaver dissection and its potential implication for clinicians. On literature search in Google and PubMed, in the month of November 2014, we did not come across the variations described in our article.

CLINICAL PROBLEM ADDRESSED

Reconstructive flap coverage of the ankle and foot is one of the options in the surgical treatment of chronic nonhealing ulcers of the diabetic foot and defects following trauma. Its use has been advocated by various authors in the reconstruction of defects and ulcers of ankle and foot with an exposed bone, joint, or tendon, as well as in chronic osteomyelitis.⁴⁻⁶ The usage of local muscle flaps continues to be the choice of coverage for small wounds as they are reliable and inexpensive alternatives to microsurgical-free flaps.⁴ The AH muscle flap is one of the local flap options and its advantages revolve around appropriate muscle girth, easy surgical isolation of the muscle and its vessels, lack of donor-site deficit, and positive long-term outcomes.^{4,5,7} Surgical isolation has previously been made simple by its unvaried anatomy and easy delineation of accompanying vessels, thus resulting in a short operative period.⁵ Knowledge of the muscle's anatomy plays a key role in its surgical isolation, and the presence of a variation could potentially influence the surgical outcome. Hence, this article highlights the anatomical variation of AH and its implication to clinicians.

MATERIALS AND METHODS

The anatomical variation in AH was identified during routine cadaver dissection in both feet of a 45-year-old, embalmed, male Indian cadaver in the Department of Anatomy of Jawaharlal Institute of Postgraduate Medical Education and Research (JIPMER), Pondicherry, India. No signs of apparent deformity were noted in both feet. On careful dissection, the muscle attachments and accompanying neurovascular bundle were delineated. Measurements such as total muscle length, tendon length, and muscle belly width were recorded using a measuring tape and photographs were taken.

RESULTS

The following were the normal findings noted:

1. The muscle had an arciform morphology (Fig. 1).

Figure 1. The arciform morphology of left abductor hallucis (AH). To see this illustration in color, the reader is referred to the web version of this article at www.liebertpub.com/wound

2. The total length of the muscle was 16 cm. The breadth of the muscle belly on the left and right side was 2 and 2.3 cm, respectively.
3. The proximal end of the muscle had attachments to the distal border of flexor retinaculum and posterior calcaneal tuberosity.
4. Distally the tendon was attached by two slips, medial larger slip to the base of proximal phalanx of hallux and lateral smaller slip to the medial sesamoid bone inferior to the head of first metatarsal bone (Fig. 2).
5. The muscle was innervated by a branch of the medial plantar nerve. A branch of the medial plantar artery entered the inferior surface of the muscle ~5 cm from the origin.

The following were the variations observed:

1. The length of the muscle belly was 5.8 cm, the tendon measured was 10.2 cm, and the tendon: muscle length ratio was 1.76.
2. Inferiorly, the muscle had innumerable atypical attachments to the medial intermuscular septum arising from the junction of the cen-

Figure 2. Distal attachment of right AH by two slips: medial slip (A) to the base of proximal phalanx of hallux and lateral slip (B) to the medial sesamoid bone lateral to the flexor hallucis longus (FHL) tendon. To see this illustration in color, the reader is referred to the web version of this article at www.liebertpub.com/wound

tral and tibial components of the plantar aponeurosis, medial surface of the first metatarsal and the intermuscular septum between AH and flexor hallucis brevis (Figs. 3–5). These attachments were in the form of tough tendinous slips, and they extended up to three-quarters of the inferior surface of the variant muscle (Fig. 3). Medially, a few fibers were continuous with deep fascia over the dorsum of the foot.

DISCUSSION

The arciform morphology observed in AH is usually more common than the straight pattern.² The innervation by a branch of the medial plantar nerve and arterial supply by a branch of the medial plantar artery are identical to the previous studies and descriptions.^{1,2}

The variant muscle in this report had a total length of 16 cm and a muscle belly width of 2 and 2.3 cm on the left and right side, respectively. These measurements are comparable to the results of a study by Agawany and Meguid on AH, involving 15 cadaveric feet. They reported a mean total muscle length of 14.29 ± 1.47 and a mean muscle width of 2.20 ± 0.43 cm.² The tendon: muscle length ratio of 1.76 observed is noticeably higher than their reported mean of 0.56 ± 0.07 .² A ratio of 0.56 means the muscle tendon and belly occupy almost equal lengths in the total muscle. A high ratio of 1.76, despite normal muscle length, clearly shows that the tendon occupies up to three-quarters of total muscle length and only a small length is occupied by the muscle belly.

Figure 3. Arrows showing tendinous slips of attachment of inferior surface of left AH to intermuscular septa. To see this illustration in color, the reader is referred to the web version of this article at www.liebertpub.com/wound

Jiang *et al.* reported a mean total muscle length of 13.4 ± 1.0 cm and mean muscle width of 1.8 ± 0.1 cm in six patients who underwent AH flap surgery for facial palsy.⁷ When compared to these measurements, our variant muscle had a smaller muscle belly length. One of the advantages of AH, as a surgical flap, is its apt muscle size and bulk.⁷ A smaller muscle size may not provide adequate coverage.

The distal attachment of AH by two slips, a medial slip to the base of the proximal phalanx of hallux and lateral slip to the medial sesamoid bone inferior to the head of the first metatarsal, as seen in this variant, is seen in 33% of cases.² The more common form (46%) of a distal attachment is solely to the base of proximal phalanx of hallux without any attachment to the sesamoid bone.²

The innumerable proximal attachments are the striking feature of this variation (Figs. 3–5). The presence of tough tendinous attachments to the medial intermuscular septum at the junction of central and tibial components of the plantar aponeurosis, medial surface of the first metatarsal,

Figure 4. Arrows showing attachments of right AH to first metatarsal. To see this illustration in color, the reader is referred to the web version of this article at www.liebertpub.com/wound

and the intermuscular septum between AH and flexor hallucis brevis has not been described in the literature previously. The presence of such strong attachments could interfere with its surgical mobilization during flap preparation.⁵ This varied anatomy could also hinder with identification of the neurovascular pedicle. Both situations could result in a prolonged operative time and duration of surgery is a proven risk factor for surgical-site

Figure 5. Arrows showing the tough tendinous attachments of right AH to the first metatarsal bone and intermuscular septa. To see this illustration in color, the reader is referred to the web version of this article at www.liebertpub.com/wound

infection.⁸ This is of greater concern in patients with diabetes as (a) they are a group of patients who commonly undergo surgical flap reconstruction for foot ulcers, (b) they have a relatively high incidence of foot infections, which require stringent control and treatment,⁶ and (c) they are a group of patients in whom management of foot ulcer and infection is challenging.⁶ The ultrasound is reported to be a reliable and cost-effective method of assessing dimensions of AH.⁹ Its inclusion in the preoperative workup could be considered in patients planned for an AH flap reconstruction, as it can provide the surgeon, information regarding muscle girth before surgery. At present, literature regarding the anatomy and variations in AH is minimal. In the future, larger cadaveric anatomical and imaging studies should be done to provide further information and determine how widespread this anatomical variation is.

INNOVATION

There is very scarce literature describing the anatomy of AH and a description of this particular variation was not found during a literature search.

AUTHOR DISCLOSURE AND GHOST WRITING

No competing financial interests exist. The content of this article was expressly written by the authors listed. No ghostwriters were used to write this article.

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TAKE-HOME MESSAGE

The AH muscle flap is used in reconstruction surgery for the coverage of ankle and foot wounds and ulcers. The presence of an anatomical variation, reported in this article, could influence surgery by interfering with its surgical isolation, causing difficulty in identification of the neurovascular pedicle or result in insufficient coverage. Prior assessment of muscle morphology may be planned by ultrasound. Studies on a larger scale may be planned to understand its clinical impact.

chief of the Journal of Society for Wound Care & Research (JSWCR). He organized the 2nd International Conference of the Society for Wound Care and Research in October 2013. **Dr. Suma Hottigoudar Yekappa, MD** (Anatomy) is Associate Professor in the Department of Anatomy at JIPMER, Pondicherry, India, and is actively involved in teaching and research related to anatomy and molecular biology. **Dr. Harsha Pratap** is pursuing her postgraduation (MD) in the Department of Anatomy, JIPMER, Pondicherry.

REFERENCES

1. Standring S, ed. *Gray's Anatomy: The Anatomical Basis of Clinical Practice*, 40th ed. Edinburgh: Churchill-Livingstone, Elsevier, 2008.
2. Agawany AE, Meguid EA. Mode of insertion of the abductor hallucis muscle in human feet and its arterial supply. *Folia Morphol (Warsz)* 2010;69:54–61.
3. Calancie B, Molano MR, Broton JG. Abductor hallucis for monitoring lower-limb recovery after spinal cord injury in man. *J Spinal Cord Med* 2004;42: 573–580.
4. Attinger CE, Ducic I, Cooper P, Zelen CM. The role of intrinsic muscle flaps of the foot for bone coverage in foot and ankle defects in diabetic and nondiabetic patients. *Plast Reconstr Surg* 2002;110: 1047–1054.
5. Albarah A, Zaid N, Darwish A, Kamel I. Double flap reconstruction (abductor hallucis muscle and planter flap) for chronic calcaneal osteomyelitis. *J Plast Reconstr Surg* 2012;36:239–243.
6. Vuorisalo S, Venermo M, Lepäntalo M. Treatment of diabetic foot ulcers. *J Cardiovasc Surg* 2009;50: 275–291.
7. Jiang H, Guo ET, Ji ZL, Zhang ML, Lu V. One-stage microvascular free abductor hallucis muscle transplantation for reanimation of facial paralysis. *Plast Reconstr Surg* 1995;96:78–85.
8. Korol E, Johnston K, Waser N, et al. A systematic review of risk factors associated with surgical site infections among surgical patients. *PLoS One* 2013;18:8.
9. Hing WA, Rome K, Cameron AF. Reliability of measuring abductor hallucis muscle parameters using two different diagnostic ultrasound machines. *J Foot Ankle Res* 2009;16:33.

Abbreviations and Acronyms

AH = abductor hallucis
FHL = flexor hallucis longus