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Surgical anatomy of the lower trapezius tendon transfer

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Background: The precise surgical anatomy of the lower trapezius tendon transfer has not been well described. A precise anatomic description of the different trapezius segments and the associated neurovascular structures is crucial for operative planning and execution. We aimed (1) to establish a reliable demarcation between the middle and lower trapezius, (2) to establish the precise relationship of the main neurovascular pedicle to the muscle belly, and (3) to evaluate the utility of the relationships established in (1) and (2) by using the results of this study to perform cadaveric lower trapezius tendon harvest.
Methods: In phase 1, a single surgeon performed all measurements using 10 cadavers. In phase 2, 10 cadaveric shoulders were used to harvest the tendon by using the relationships established in phase 1.
Results: We found anatomically distinct insertion sites for the lower and middle trapezius. The lower trapezius inserted at the scapular spine dorsum and the middle trapezius inserted broadly along the superior surface of the scapular spine. The distance from tip of tendon insertion to the nearest nerve at the most superior portion of the lower trapezius was 58 mm (standard deviation $\pm$ 18). By use of these relationships, there were no cases of neurovascular injury during our cadaveric tendon harvests.
Conclusion: The lower trapezius can be reliably and consistently identified without violating fibers of the middle trapezius. Muscle splitting can be performed safely without encountering the spinal accessory nerve (approximately 2 cm medial to the medial scapular border).
Level of evidence: Basic Science Study, Anatomy, Cadaver Dissection.

Keywords: Surgical anatomy; surgical landmarks; lower trapezius; tendon transfer; cadaveric study; spinal accessory nerve

Numerous surgical options have been proposed for irreparable rotator cuff tears, including rotator cuff débridement,[6] partial rotator cuff repair,[10] biceps tenotomy or tenodesis,[17] tendon transfer,[7] and arthroplasty.[13] There exists concern with arthroplasty regarding longevity of implant survivorship in the population of younger, more active patients. Such concern often precludes the use of arthroplasty in this specific population. As such, tendon transfers may offer a more reasonable and acceptable option to decrease pain and to improve function for younger patients.

Classically, the latissimus dorsi tendon transfer was performed for posterosuperior rotator cuff-deficient shoulders

Institutional Review Board approval was not necessary for this cadaveric, basic science study.

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with the goal of restoring elevation and external rotation and providing a more balanced biomechanical state to the glenohumeral joint. However, the mechanism by which the latissimus dorsi tendon transfer exerts its effects remains controversial. Trapezius transfers have previously been described in the literature, with historically poor results being attributed to elongation of the fascia lata augmentation and scarring.[14,15] Of note, most early published reports involved the isolated transfer of the upper portion of the trapezius.[1,9,11,15] More recently, the lower trapezius transfer has been used successfully to improve elevation and external rotation in patients with brachial plexopathies.[2,4,5]

The lower trapezius tendon transfer may provide a more direct line of pull that improves external rotation relative to other tendon transfers. Despite limited evidence supporting its use, the lower trapezius tendon transfer may be a viable alternative option for patients with irreparable posterosuperior rotator cuff tears. Of note, a recent cadaveric biomechanical study illustrated that the lower trapezius transfer resulted in superior restoration of shoulder external rotation with the arm at the side relative to the latissimus dorsi tendon transfer.[8]

The anatomy of the trapezius muscle, with its demarcations into upper, middle, and lower thirds, is poorly defined. Identifying and distinguishing the lower trapezius fibers represent some of the greatest intraoperative challenges during trapezius tendon transfers. Further, the middle and lower trapezius segments are vital structures that support scapular motion, especially if a patient requires subsequent glenohumeral fusion. Proper identification of the lower trapezius is thus essential. There also exist concerns for denervation during splitting of the middle and lower trapezius during trapezius tendon transfer as the relationship of the neurovascular pedicle within the muscle belly has not been well established (Fig. 1). Most of the current pertinent literature focuses on the anatomy of the upper trapezius, in the region of the posterior triangle of the neck.[12,16] Dailiana et al[3] described the location of the spinal accessory nerve intramuscularly, but only briefly commented that the intramuscular portion "followed an oblique caudal course towards the middle and lower parts of trapezius." A more precise anatomic description is necessary for operative planning.

The purpose of this cadaveric study was to better define the surgical anatomy of the trapezius transfer by (1) establishing a reliable demarcation between the middle and lower trapezius, (2) establishing the precise relationship of the main neurovascular pedicle to the muscle belly at the level of the muscle splitting, and (3) evaluating the utility of the relationships established in purposes (1) and (2) by using the results of this study to perform cadaveric lower trapezius tendon harvests.

Materials and methods

A cadaveric anatomy study consisting of 2 phases was performed. The first phase consisted of defining the precise anatomy of the trapezius muscle and its neurovascular pedicle in 20 cadaveric shoulders. The second phase involved using this information to perform trapezius tendon harvests in 10 cadaveric shoulders through limited incisions in an effort to determine the utility of relying on the relationships determined in the first phase.

Figure 1 An illustration demonstrating the neurovascular pedicle within the trapezius muscle belly.

Phase 1

Ten fresh frozen adult cadavers (20 shoulders) were obtained from the Los Angeles County Fresh Tissue Dissection Laboratory/Surgical Skills Center. Each specimen was secured in the prone position, and a wide T-shaped incision was made. Both the skin and subcutaneous tissue were reflected to expose the origin and insertions on the scapula (Fig. 2, *A*). Next, the triangular aponeurosis, which corresponds to the middle trapezius, was identified, and its caudal and rostral extent was noted by counting the spinous processes (the C7 vertebra served as a reference point). We then noted the inferior extent of the lower trapezius origin.

During our dissections, we confirmed that the middle trapezius (corresponding to the area of aponeurosis) inserts broadly along the scapular spine when it is traced laterally. The lower trapezius fibers, beginning at the spinous process inferior to the triangular aponeurosis, converge at its insertion on the dorsal surface of the scapula at the dorsal trapezius tubercle. The length of the tendinous portion of the lower trapezius and the width at the myotendinous junction were measured. All measurements were performed with a hand-held sliding digital caliper (General Tools & Instruments, New York, NY, USA). Measurements were performed by a single observer.

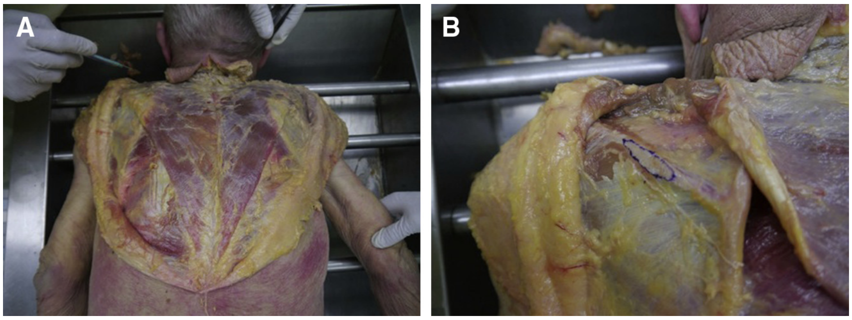

Figure 2 (**A**) A cadaveric dissection with both the skin and subcutaneous tissue reflected to fully expose the origin and insertion of the trapezius. (**B**) A photograph demonstrating elevation of lower trapezius insertion off of the medial edge of the scapular spine to expose the footprint (marked with *oval*) and triangular bare area.

Figure 3 The hook technique is used to identify the lower portion of the trapezius. The index finger is used to hook over the smooth bare area of the medial aspect of the dorsal scapula.

The fibers of the lower trapezius insertion were then carefully reflected off of the medial edge of the spine of the scapula, exposing the footprint and the adjacent, medial smooth triangular region of scapula (bare area) (Fig. 2, *B*). The length and width of the footprint and the base and height of the bare area were then measured. During these dissections, it was determined that the optimal method for identifying and isolating the tendon of the lower trapezius alone was for the surgeon to ‘‘hook’’ his or her index finger laterally beneath the trapezius and over the smooth triangle to grab the dorsal, lower fibers (Fig. 3).

The spinal accessory nerve and the main muscular branch of the superficial transverse cervical artery were identified on the ventral surface of the trapezius. With use of 18-gauge needles, the pathway of the neurovascular bundle was marked by inserting the needles through the trapezius from the dorsal to the ventral aspect of the muscle belly (Fig. 4, *A*). Next, a vector was determined from the medial edge of the spine of the scapular footprint to the spinous process of the first vertebra from which the lower trapezius originates. The distance from the insertion site to the nerve was measured in line with this vector. The distance was also measured in the same manner for the subsequent inferior 3 spinous processes.

Phase 2

The second phase of our study involved investigating the ‘‘safety’’ and utility of our technique, which stresses the maintenance of a safe distance from the neurovascular structures encountered during harvest of the trapezius tendon. Using 10 cadaveric shoulders, we performed the harvesting portion of the trapezius tendon transfer and subsequently dissected out the spinal accessory nerve. With use of the palpable landmarks of the medial scapular border and the scapular spine, a 5-cm vertical incision was made 1 cm lateral to the scapular border. This location was selected to center our incision over the scapular spine tubercle based on the average

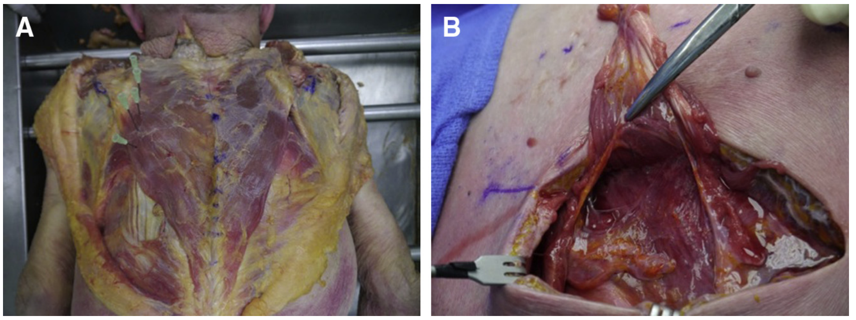

Figure 4 (**A**) The pathway of the neurovascular bundle as marked by 18-gauge needles placed ventral to dorsal through the trapezius muscle belly. (**B**) A photograph demonstrating inversion of the muscle belly to confirm that the neurovascular bundle is intact after performance of cadaveric tendon transfer.

Table I Anatomic variations

	Mode	Range	Pattern distribution
Triangular aponeurosis (middle trapezius)	C5-T1	C5-C6 to T1-T3	C5-T1 (50%), C5-T2 (30%), C6-T2 (10%), C5-T3 (10%)
Lower extent of trapezius	T10	T9-T12	T10 (50%), T9 (20%), T11 (20%), T12 (10%)

width of the bare area as measured in phase 1. The edge of the trapezius muscle was traced up toward the spine, and then the aforementioned hook technique was employed to identify and to detach the fibers of the trapezius off of its insertion site. Observing the safe zone determined in phase 1 of our study, we performed a limited longitudinal split of the tendon and muscle of <20 mm. For closer evaluation, the shoulders were then opened as described in the initial dissections of phase 1. We confirmed that the reflected fibers corresponded to the lower trapezius without any portion of the middle trapezius being sacrificed. The muscle belly was then reflected off of its insertion to identify the spinal accessory nerve and to measure the distance of the neurovascular bundle from the insertion site. We then confirmed that the nerve was not lacerated by direct visualization (Fig. 4, *B*).

Results

We describe the observed variations in the basic anatomy of the trapezius in Table I. In the most common pattern, the trapezius extended caudally to the T10 vertebra (range, T9-T12). The triangular aponeurosis, corresponding to the middle trapezius, typically was noted to span C5-T1. We noted that the lower trapezius (defined as the portion of trapezius inferior to the triangular aponeurosis) was distinct from the middle trapezius as it came together as a tendinous confluence. This confluence inserted, with a limited footprint, onto the dorsum of the spine of the scapula. In contrast, the middle trapezius inserted broadly along the length of the superior surface of the scapular spine. We also identified an important anatomic landmark consisting of a triangular bony region at the junction of the medial border of the scapula and the scapular spine. We found that this portion of bone was smooth and free from the tendon insertion, allowing easy identification of the lower trapezius footprint. Further, we found that this landmark allows one to quickly identify the entire footprint by sliding a finger along the undersurface of the trapezius and over the smooth triangle, thereby allowing the finger to act as a hook. Table II shows the mean lengths of the tendon and associated anatomy of the tendon insertion. Notably, the height of the smooth triangle was 23 mm (standard deviation [SD] = 5 mm), whereas the average length of the footprint was 30 mm (SD = 7 mm). Finally, we noted the length of the tendinous portion of the trapezius, measuring from the tip of the lower trapezius insertion, to be 49 mm (SD = 9 mm).

Table II Average measurements*

	Mean	SD	CI
Length of footprint	29.4	7.4	3.3
Height of smooth triangle	22.5	5.0	2.2
Length of tendinous portion to end of footprint	48.7	9.0	3.9

SD, standard deviation; *CI*, confidence interval.
* All distances in millimeters.

The spinal accessory nerve was isolated and its course was traced along the undersurface of the trapezius muscle. In all specimens, the distance from the insertion footprint gradually increased as it traveled caudally along the lower trapezius. As such, the distance from tip of tendon insertion to the nerve at its closest distance is at the most superior portion of the lower trapezius. Although multiple measurements were calculated initially, we report in Table III only the mean trajectory to the most superior portion of the lower trapezius as our goal was to determine a minimal safe distance to the nerve. The mean distance for all

Table III Distance from tendon tip insertion to nerve*

	Mean	SD	CI
Phase 1	62	20	9
Phase 2	49	11	7
Combined	58	18	7

SD, standard deviation; *CI*, confidence interval.
* All measurements in millimeters.

samples was 58 mm (SD = 18), with the nerve being measured as close as 23 mm in 1 specimen.

Of the 10 cadaveric shoulders investigated in phase 2 of our study, we had no cases of neurovascular laceration using our proposed surgical technique. This reinforced the anatomic relationships determined in phase 1.

Discussion

The precise anatomic relationships of the different segments of the trapezius and its neurovascular structures have not been well established. In our cadaveric study, we investigated the pertinent anatomic relationships critical to the lower trapezius tendon transfer.

There are limitations to our study. We acknowledge the inherent limitation in relying on cadaveric dissections, given reflection of the lower trapezius and the inherent potential for change in the soft tissue relationships during measurements. In addition, measurements were performed manually, and therefore there is the risk for decreased precision due to human error when measurements are recorded at the level of millimeters. Although we had no instances of direct neurovascular injury during trapezius tendon harvest in this cadaveric study, in vivo neurovascular injury may also include stretch or vascular insult with tendon transfer. Also, surgery is often performed in the lateral decubitus position as opposed to the prone position used for cadaveric dissection. We did, however, limit motion by securing all specimens in a stable position. We also concede that the tendon transfers were not performed in vivo. Nevertheless, we believe that our results offer valid and clinically pertinent insight into the surgical anatomy of the lower trapezius tendon transfer as we used a large number of specimens (30 in total) and a standardized technique for dissection and measurement.

Our anatomic study showed that the fibers of the lower trapezius can be identified using our hook technique without violating fibers of the middle trapezius. We found that the lower trapezius insertion consistently converges at the dorsal scapular spine tubercle, making it easily identifiable. In contrast, the middle trapezius inserts broadly along the length of the superior surface of the scapular spine. These findings offer a precise, reliable, and reproducible relationship that can be used to identify the lower trapezius during a trapezius tendon transfer. Further, our results maintain clinically relevant implications regarding the proper allograft length in the lower trapezius tendon transfer. We noted that the length of the tendon of the lower trapezius was on average 49 mm. Intraoperatively, the tendon of the lower trapezius is attached to an Achilles tendon allograft to allow proper excursion for attachment to the humeral head greater tuberosity. Typically, 40 mm of the Achilles tendon allograft tendon is overlapped with the lower trapezius tendon to allow secure fixation. This finding confirms that a 40-mm overlap between the allograft and lower trapezius tendon incorporates most of the native tendon for optimal fixation.

We also aimed to elucidate a "safe" distance for muscle splitting in the lower trapezius tendon transfer. It is imperative to split the trapezius between the middle and lower trapezius segments to allow proper excursion of the tendon transfer. We found that dissections can often be performed without encountering the spinal accessory nerve until approximately 58 mm medial to the tip of the trapezius tendon. Also, dissection medial to the tendon should often be safe as the average tendon length (49 mm) was less than the average distance to the nerve (58 mm). However, caution should be used as the nerve was found to be as close as 23 mm in 1 cadaver.

Finally, we posit that our results offer safe and reliable anatomic relationships for the lower trapezius tendon transfer. Of the 10 cadaveric lower trapezius tendon transfers that we performed, we had no cases of direct neurovascular injury using our technique, which stressed the anatomic relationships and distances that we determined.

Conclusions

Our results offer clinically valuable insight into the anatomic relationships of the lower trapezius tendon transfer. The lower trapezius insertion consistently converges at the dorsal scapular spine tubercle and the middle trapezius inserts broadly along the length of the superior surface of the scapular spine. We found that dissection medial to the tip of the tendinous portion of the lower trapezius can be performed a minimum of approximately 23 mm and on average 58 mm without encountering the spinal accessory nerve.

Disclaimer

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