The relationship between various anatomical landmarks used for localizing the first rib during surface palpation

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Objectives: To assess the relationship between anatomical landmarks used to locate the first rib during surface palpation. One currently cited technique suggests locating the width of the transverse processes (TPs) of the first cervical vertebrae (C1) to determine the estimated width of the first thoracic vertebrae (T1) TP, allowing for subsequent palpation of the first rib laterally to the transverse process of T1. Based on anatomical structural relationships, the authors propose an additional method of locating the first rib, lateral to T1 TP, by palpating through the trapezius muscle at the width of the mastoid process (MP).

Methods: Overlying tissue of the bilateral MP, C1 TPs, and T1 TPs of 28 cadavers were removed. Measurements of the left to right spans at the following structures were collected using a digital caliper: mastoid process, C1 TP, and T1 TP. Measurements were used to determine the agreement between each anatomical structural span.

Results: The mean absolute difference (standard deviation, SD) between C1 TP span versus T1 TP span was 3.9 (± 2.58) mm with an intraclass correlation coefficient (ICC) of 0.88 (95% CI=2.9–4.9). The mean absolute difference between MP span and T1 TP span was 35.4 (± 6.46) mm with an ICC of 0.71 (95% CI=33.0–37.8).

Discussion: This study confirms the anatomical accuracy and feasibility of using the C1 TP span to determine the general width of the T1 TP span while palpating for the first rib just lateral to the T1 TP. Additionally, this study demonstrates that the more easily palpated mastoid process serves as an effective landmark to identify a width sufficiently lateral to the T1 TP, appropriate for first rib palpation through the trapezius muscle.

Keywords: First rib, Reliability, Surface anatomy, Manual therapy, Bone morphology

Introduction

First rib dysfunction has been observed in thoracic outlet syndrome and pathologies of the cervicothoracic junction.^{1–3} The first rib serves as an attachment for several muscles and comprises the floor of the thoracic outlet costoclavicular space.⁴ Many factors can contribute to neurovascular tissue compression at the thoracic outlet. However, the most basic is abnormal anatomy, to which dynamic, static, congenital, and traumatic factors may contribute.^{5,6} Structural abnormalities of the first rib have been reported and can compromise the brachial plexus within the thoracic outlet.³ Additionally, motion dysfunction of the first rib can change the resting length of the scalene muscles,

leading to compression of the brachial plexus as it passes over the first rib between the anterior and middle scalenes.⁷ Similarly, first rib motion dysfunction and malposition narrows the costoclavicular space resulting in brachial plexus compression or angular tension. Often the first rib is stuck in an inspired or elevated position as a result of limited, cranial, ligamentous support at the first costovertebral joint.¹ Restoration of proper first rib movement and position can be instrumental in reducing symptoms associated with thoracic outlet syndrome (Fig. 1).^{1,5,8,12} Clinicians are encouraged to use a manual spring test at the first rib to assess its passive mobility status. The results of this testing could indicate the need to incorporate mobilization and/or manipulation of the costovertebral and/or costotransverse joints to address first rib movement dysfunctions.^{1,5,8,12}

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Figure 1 Diagram showing the thoracic outlet. (a) Clavicle; (b) first rib; (c) coracoid process; (d) middle scalene; (e) posterior scalene; (f) brachial plexus; (g) subclavian artery; (h) pectoralis minor; (i) sternocleidomastoid. Reprinted with permission from: Hooper TL, Denton J, McGalliard MK, Brismée JM, Sizer PS, Jr. Thoracic outlet syndrome: a controversial clinical condition. Part 1: Anatomy, and clinical examination/diagnosis. *J Man Manip Ther.* 2010;18:74–83.

Anatomical landmark palpation skills have been shown to be an important component in manual therapy.⁹ Effective assessment and treatment of the first rib depends on accurate localization via palpation. Once the first rib is located, clinicians are encouraged to test and mobilize the first rib by placing the mobilizing/testing hand in a position sufficiently lateral to the first costotransverse joint avoiding the transverse process of the first thoracic vertebra (T1). Exerting a manual force over the T1 transverse process (TP) instead of on the first rib would produce an ineffective first costovertebral or costotransverse joint mobilization and may be uncomfortable for the patient. Therefore, any strategy (including the use of knowledge of anatomical spatial relationships used in the systematic methodology of surface anatomy palpation) that assists the manual therapist in accurately localizing the first rib and avoiding the T1 transverse process could optimize the technique.

In order to achieve accurate localization of the first rib, which is often challenging to palpate directly, Reichert recommends palpating the C1 transverse processes in the proximity of the mastoid processes and then establishing the distance between the lateral tips of the C1 transverse process (C1 TP span).¹⁰ He surmises that this distance (C1 TP span) is the same

as the distance between the lateral tips of the T1 transverse process (T1 TP span).¹⁰ After finding the C1 TP span and projecting that width to the superior surface of the upper trapezius, the clinician can estimate the T1 TP span and palpate for the position of the first rib sufficiently lateral to the T1 TP in preparation for mobilization.

The technique described above requires accuracy in localizing the C1 TP and consistency in projecting that span to the superior portion of the patient's upper trapezius. In this manuscript, we will call this technique the 'C1 to T1 technique' for localizing the first rib. To date, no study has examined the anatomical relationship between the C1 TP span and the T1 TP span, in cadavers. Moreover, because of the perceived challenges associated with the use of this technique, it may benefit clinicians to establish less complex means to locate the first rib in a position sufficiently lateral to the T1 TP. While no specific citation was identified describing difficulty in locating the C1 TP, it can be inferred from clinical and educational instructional experience that overlying tissue and the close proximity to the base of the skull can make the proper localization of C1 TP challenging. The lack of previous studies examining the anatomical spatial relationships between these structures, and the desire to identify an anatomically sound, simple, and potentially more efficient technique for localizing the first rib provided the impetus for this study.

This study had two goals. First, we examined the anatomical spatial relationship between the C1 TP span and the T1 TP span. Establishing this relationship would validate the 'C1 to T1 technique' and assist the clinician in avoiding the T1 transverse process when mobilizing the first rib. Second, we aimed to identify an alternative landmark, the mastoid process (MP), which the clinician could successfully use as a relational reference point when attempting to localize the first rib in a position sufficiently lateral to the T1 TP. This 'MP to first rib technique' simply requires that clinicians use the width of the MP to provide a lateral reference point as they palpate for the first rib through the superior trapezius muscle. This alternative method may provide a less technically demanding approach with potentially reduced error, which might facilitate a reduction in the clinician's effort to localize this important structure.

Methods

Twenty-eight, prone lying, embalmed, human cadaveric specimens from the Texas Tech University Health Sciences Center's gross anatomy laboratory were used during this study. All cadaveric specimens were handled in accordance with university policy and State of Texas regulations as defined by the

Table 1 Caliper measurements: intrarater intraclass correlation coefficients (ICC)

	ICC _(3,1)	95% CI	
		Lower	Upper
MP	0.94	0.89	0.97
T1 TP	1	0.99	1
C1 TP	1	0.99	1

Note: MP=mastoid process; T1 TP=T1 transverse process; C1 TP=C1 transverse process; CI=confidence interval.

Table 2 Widths of the segmental process spans (*n*=28)

	Span widths (mm)			95% confidence interval (mm)	
	Mean	SD	Range	Lower CI	Upper CI
C1	78.8	7.4	66.6–91.6	76.1	81.5
T1	78.8	6.9	62.3–93.4	76.2	81.4
MP	114.2	6.7	103.1–126.1	111.7	116.7

Note: C1=first cervical vertebra transverse process span; T1=first thoracic vertebra transverse process span; MP=mastoid process span; SD=standard deviation.

Texas Anatomical Board. Cadaveric specimens consisted of 14 male and 14 female cadavers with an average weight of 73 kg, average height of 166.3 cm, and an average estimated Body Mass Index of 26.4. The overlying soft tissues covering the MP, C1 TP, and T1 TP, including the first costotransverse joint capsule, were removed bilaterally. All dissections were completed and examined for consistency before recording measurements. Cadavers were excluded if the presence of cervical fusion or a cervical rib was observed.

An individual rater, blinded to the measurement outcome, collected all measurement data. Measurements were collected using a Wiha digiMax® digital caliper and recorded to a precision of 0.1 mm.

To evaluate the intrarater reliability, 10 cadavers were pseudo-randomly selected and each span width was measured, using the digital caliper, three times to allow for the calculation of a mean. These mean measurements were taken at two separate time points allowing for calculation of the intraclass correlation coefficient [ICC_(3,1)] in order to determine the correlation and agreement of the repeated measures.

Data collection consisted of left to right span measurements at C1 TP, T1 TP, and the MP. The three-trial average at each span was calculated and used for comparison. Mean data were established for the three measures of each structure (span) and analyzed using an ICC_(3,k) to determine correlation and agreement between anatomical spans of interest. The mean absolute differences (MAD) and standard deviations (SDs) of these spans were calculated in order to determine clinically useful anatomical spatial relations between spans.

Results

The intrarater reliability of caliper measurements ICC_(3,1) (95% confidence interval) for the T1 TP, C1 TP, and MP span widths were 1.00 (0.99–1.00), 0.995 (0.991–0.998), and 0.94 (0.89–0.97), respectively (Table 1).

The mean (SD) widths of the C1, T1, and MP spans were 78.8 (±7.4), 78.8 (±6.9), and 114.2 (±6.7) mm, respectively. The ranges of widths for respective spans were, C1 66.6–91.6 mm, T1 62.3–93.4 mm, and mastoid 103.1–126.1 mm (Table 2). The ICC_(3,k) between the T1 TP and C1 TP span was 0.88 (*P*=0.0001) with an MAD (SD) of 3.9 (±2.6) mm. The ICC_(3,k) between the T1 TP and mastoid process spans was 0.71 (*P*=0.002) with a MAD (SD) of 35.4 (±6.5) mm (Table 3). The C1 span was larger than its corresponding T1 span in 16 cadavers, while the T1 span was larger than C1 in 12 cadavers. Neither the T1 span or the C1 span was ever found to be wider than the MP span.

Discussion

The results of this study indicate that there is a strong anatomical spatial relationship between the C1 TP span and the T1 TP span.¹¹ As a result, based on the anatomical size relationship between the C1 and T1 TP spans, if a clinician elects to use the spatial relationship proposed in the C1 to T1 method to localize the superior aspect of the first rib in preparation for mobility testing and mobilization, he/she can successfully avoid the T1 transverse process (Fig. 2). Such an approach to testing and treatment has been documented in the literature.⁴ Clinicians often elect to mobilize the first rib, emphasizing the costovertebral joint by pushing on the superior surface of the first rib in a

Table 3 Absolute difference and intraclass correlation coefficients (ICC) for C1 TP–T1 TP spans and MP–T1 TP spans

	ICC _(3,k)	Absolute difference (mm)		95% confidence interval (mm)	
		Mean	SD	Lower	Upper
C1 TP–T1TP	0.88	3.9	2.6	2.9	4.9
MP–T1 TP	0.71	35.4	6.5	33.0	37.8

Note: C1 TP=C1 transverse process span; T1 TP=T1 transverse process span; MP: mastoid process span; CI=confidence interval; SD=standard deviation.

Figure 2 Skeletal model with delineated marking for anatomical landmarks used in the study. (1) Mastoid process: horizontal dashed line demonstrates the mastoid process width (MP span). (2) First cervical (C1) vertebra: horizontal dotted line at C1 demonstrates the C1 TP width (C1 TP span). (3) First thoracic (T1) vertebra: horizontal dotted line at T1 demonstrates T1 TP width (T1 TP span). The vertical dotted line demonstrates the anatomical relationship between the lateral width of the C1 TP and the lateral width of the T1 TP. (4) First rib outside the T1 TP: vertical dashed line demonstrates the anatomical relationship between lateral width of the mastoid process and the first rib. This relationship suggests that palpation for the first rib (through the upper trapezius, not pictured) at the lateral width of the mastoid process should place the clinician on the first rib.

direction toward the contralateral hip.⁸ This mobilization aims to increase the space between the first rib and the clavicle by moving the first rib into a greater position of expiration. This positional change may reduce compression or angular tension of the brachial plexus during resting position and functional activities such as arm elevation or shoulder girdle depression.^{8,12,13} Our results showed a 3.9 mm MAD between the C1 TP span and T1 TP span, indicating comparable distances between the lateral tips of the transverse processes at both C1 and T1 spinal levels. While the difference between the spans was relatively small, one should be mindful of such differences because the space in which clinicians must incorporate manual therapy, to the first rib, in this region is relatively confined. Such tight spaces merit clinician accuracy in localizing landmarks so to avoid unwanted discomfort and ineffective therapeutic results. MAD was used because we observed variability between the width of the C1 and T1 spinal levels, where neither structure measured consistently wider than the other. In approximately half of the cadavers, the C1 TP span was slightly wider than the T1 TP span. However, in the other half of the cadavers, the T1 TP span was slightly wider than the C1 TP span. This variability in T1

TP spans, as well as variability in the width of the clinician's hand, means that a point approximately 1.5 cm lateral to the boundary of the projected span (from C1 TP to T1 TP) should be used in order to ensure that the clinician is lateral to the T1 TP.

While the results of this study indicate that the anatomical size relationships between the C1 and T1 TP spans are similar and reliable, using the C1 to T1 method to localize the first rib for mobilization may present with complexities. These complexities have been realized by the authors in clinical and educational experiences with new clinicians or entry-level professional students. In response, a less complex model for localizing the first rib is merited. We were able to identify the anatomical size relationship between the MP to first rib as reliable and consistent. As a result, we propose the MP to first rib method for locating the first rib during testing and mobilization as a simple and anatomically reliable method for clinical application. Because the mean MP span was over 3 cm wider than the T1 TP span, this placed the localization (following the MP to first rib technique) on the first rib at least 1.5 cm lateral to the TP span boundary, unilaterally. By choosing to use the spatial

relationship of the mastoid process span, in this fashion, the clinician can locate the first rib through the upper trapezius muscle, at the width of the MP, with confidence, and be assured that the mobilizing hand is loading the first rib and not the T1 TP. A clinician's use of the MP to first rib method may present a less complex approach to optimizing hand placement for first rib testing and mobilization compared to the C1 to T1 method.

Our study did not establish the lateral border of the first rib in our cadavers. While this was not an aim of the study and therefore not reported, it raises a possible limitation to the use of the 'MP to first rib technique'. However, we observed that the 1.5 cm point lateral to the T1 TP placed the clinician on the most appropriate point for mobilization of the first rib. In no cases did it appear that the first rib took such an immediately anterior path from the first costotransverse joint that palpation at the point of the MP would be too lateral to reach the first rib.

The mean age of our cadaveric specimens was 79 years. This advanced average age increases the likelihood of bony structural changes, which could possibly be a cause for abnormal findings. It is also important to note that alterations in functional anatomy and structural abnormalities may lead to dysfunction of the first rib and compression of the thoracic outlet; however, in our cadavers, the relationship between MP, C1, T1, and the first rib did not appear to be compromised. It is important to recognize that our study simply establishes the anatomical spatial relationship. It was not a goal of the current study to establish the intratester or intertester reliability of the actual clinical palpation techniques. Future studies investigating the accuracy of clinicians' ability to localize the first rib *in vivo* using the approaches described herein, confirmed with imaging such as X-ray or diagnostic ultrasound, are warranted.

Conclusion

The results of this study support the use of C1 TP span to locate the first rib lateral to the T1 TP (C1 to T1 method). However, because of potential difficulties associated with palpating the C1 TP, our study provides an alternative method using the MP to first rib method for localization of the first rib. This method involves palpation of the first rib through the upper trapezius at a point equivalent to the width of the mastoid processes.

Conflict of Interest

The authors declare that they have no conflict of interest.

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