Original Article

HEALTH SCIENCES
MEDICINE

DOI: 10.32322/jhsm.1476093
J Health Sci Med. 2024;7(4):356-360

Ultrasonographic assessment of cricothyroid membrane height in a Turkish cohort

Doğa Özdemir Kalkan[1], Nezih Kavak[2]
[1]*Department of Radiology, Ankara Etlik City Hospital, Ankara, Turkiye*
[2]*Department of Emergency Medicine, Ankara Etlik City Hospital, Ankara, Turkiye*

Cite this article as: Özdemir Kalkan D, Kavak N. Ultrasonographic assessment of cricothyroid membrane height in a Turkish cohort. *J Health Sci Med.* 2024;7(4):356-360.

Received: 30.04.2024 ◆ **Accepted**: 25.05.2024 ◆ **Published**: 30.07.2024

ABSTRACT

Aims: Cricothyrotomy is a life-saving technique utilized in emergency airway management. This study aimed to assess the variability in the height of the cricothyroid membrane (CTM) based on gender, age, and body-mass index (BMI) across different neck positions, neutral and maximally extended.

Methods: The study enrolled healthy volunteers aged 18 years and older. Participant baseline characteristics (age, gender, and BMI) were systematically documented. The height of the CTM was measured using, with the participants' necks positioned in neutral and extended postures. Associations between CTM height and demographic variables, including sex, age, height, and BMI, were evaluated.

Results: The study cohort comprised 296 individuals with a mean age of 41.84±15.76 years, ranging from 18 to 75 years. 30.3% of the participants were between 18 and 29 years old. 175 participants (59.1%) were female. The CTM height was significantly greater in the maximum extension position compared to the neutral position ($p<0.001$). CTM height in the neutral position was significantly lower in females compared to males ($p<0.001$). This difference persisted in the maximum extended position, where females also exhibited a lower CTM height than males ($p<0.001$).

Conclusion: The height of the CTM varies significantly based on gender and neck position. These variations have critical implications for performing cricothyrotomy, especially in the Turkish population, highlighting the need for tailored approaches in emergency procedures.

Keywords: Cricothyroid membrane, cricothyrotomy, ultrasound

INTRODUCTION

The cricothyroid membrane (CTM) is an essential anatomical feature located between the cricoid and thyroid cartilages at the anterior midline of the neck. Unlike its adjacent structures the more rigid thyroid and cricoid cartilages the CTM is composed of fibrous, relatively avascular tissue, lending it flexibility and surface accessibility.

Airway management is a pivotal aspect of emergency medicine practice.[1] Cricothyrotomy, also known as cricothyroidotomy, is a critical procedure in scenarios where traditional intubation is not possible, such as "cannot intubate, cannot ventilate" situations. This technique is vital in instances of upper airway obstructions, severe facial trauma, or maxillofacial injuries that preclude endotracheal intubation due to anatomical abnormalities.[2-4] The conventional cricothyrotomy approach often employs the landmark palpation technique, where pre-procedural anatomical knowledge can enhance the likelihood of success and thus mitigate associated morbidity and mortality.[4-6]

Research indicates that anatomical variations in the CTM's size and structure are prevalent across different races, genders, and age groups.[7,8] The optimal technique for cricothyrotomy typically involves maximal head and neck extension.[9] However, this position may not always be feasible in patients with conditions such as neck surgery, radiation therapy to the neck, or other neck pathologies. Understanding the CTM's height is crucial, as it informs the appropriate size of the tracheal tube to be used, thereby impacting the potential for complications during the procedure.

Ultrasonography (USG) has become a vital tool in airway management due to its non-invasiveness, lack of ionizing radiation, portability, and capability for rapid execution. Despite its many advantages, it is important to note that the accuracy of USG is operator-dependent. USG allows for the precise visualization of the upper airway's sonoanatomy and is considered the "gold standard" for point-of-care identification and measurement of the CTM.[5,10]

Corresponding Author: Doğa Özdemir Kalkan, dr_dogaozdemir@yahoo.com

This study aimed to assess the variability in the height of the cricothyroid membrane (CTM) based on gender, age, and body-mass index (BMI) across different neck positions, neutral and maximally extended.

METHODS

This single center prospective observational study was carried out from March 10 to May 10, 2024, subsequent to receiving approval from the Ankara Etlik City Hospital Clinical Researches Local Ethics Committee (Date: 06.03.2024, Decision No: 2024-204). This study was performed in line with the principles of the Declaration of Helsinki. All participants provided written informed consent, which was obtained after they were fully informed about the study's aims and methodologies.

The study included healthy volunteers aged 18 years and older. Individuals were excluded if had any known airway pathology, arthritis, restrictions in neck movement, neurological issues affecting the upper limbs, were pregnant, or had a history of neck surgery or radiation exposure.

Baseline characteristics such as age, gender, and BMI were meticulously gathered for each participant. Age was categorized as 18-29, 30-39, 40-49, 50-59, and ≥60 years. The BMI was calculated using the standard formula of weight in kilograms divided by the square of height in meters (kg/m^2), and categorized into four groups (<18.5, 18.5-24.9, 25-29.9, ≥30 kg/m^2) according to World Health Organization criteria.[11]

For the USG assessment, each participant was positioned supine on a flat patient stretcher. Their heads were supported by a pillow to maintain the neck in a neutral position, characterized by the ala tragus line being perpendicular to both the floor and the stretcher, and the external auditory canal aligned with the sternal angle to form a straight line parallel to the floor.

The USG scans commenced with the identification of the hypoechoic thyroid and cricoid cartilages. Subsequently, the height of the CTM was meticulously measured using distance calipers in the sagittal orientation. This measurement was defined as the vertical distance from the cephalad border of the cricoid cartilage to the caudal border of the thyroid cartilage in milimeters (mm).[12,13]

Following the initial measurement, volunteers were instructed to adjust their necks to a position of maximum extension. The CTM height was then remeasured under these conditions. All ultrasound scans were consistently performed using the longitudinal technique in the longitudinal plane ensuring consistency and accuracy in the measurements obtained (Figure).[14]

The USG measurements were conducted by a radiologist with ten years of experience, utilizing a LOGIQ E10 ultrasound device (GE Healthcare) equipped with a 7 MHz linear probe, which operates within a frequency range of 4.0-20 MHz. Measurements of the CTM were accurately done in centimeters using distance calipers.

Before embarking on the study, an emergency medicine physician was trained by the radiology doctor in the identification and measurement of the CTM diameters in over 10 patients for two hours. This training was essential to ensure that the emergency physician could accurately perform these measurements, although these particular patients were not included in the study.

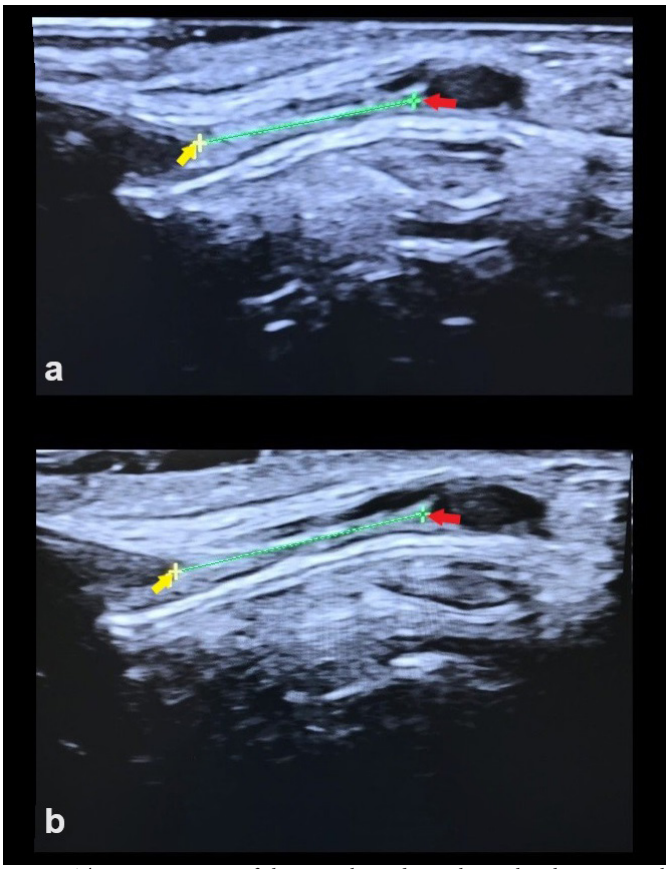

Figure. The measurement of the cricothyroid membrane height in neutral position (a), in the maximum extended position (b), the height of the cricothyroid membrane distance (green line) between the cephalad border of the thyroid cartilage (yellow arrows) and the caudal border of the cricoid cartilage (red arrows) (a,b)

In the study, both the radiology and emergency medicine doctor independently measured the CTM height of volunteers. These measurements were conducted in the specified positions without knowledge of each other's results, ensuring unbiased and reliable data collection for the interobserver agreement.

Statistical Analysis

Descriptive statistics for continuous data (such as age, etc.) included the mean, standard deviation, median, minimum, and maximum values. For categorical data, frequencies and percentages were provided. The normality of the continuous data distribution was assessed using the Kolmogorov-Smirnov test. Comparisons between age and BMI groups were conducted using the Kruskal-Wallis variance test. In cases where the Kruskal-Wallis Analysis indicated significant differences, the source of these differences between groups was further examined using the Kruskal-Wallis multiple comparison test. Gender comparisons for measurements were performed using the Mann-Whitney u test. The comparison of CTM height in the neutral and maximum extended positions was analyzed using the Wilcoxon test. The CTM height in the neutral and maximum extended positions interobserver agreement was evaluated using the intraclass correlation

coefficients. All statistical evaluations were carried out using IBM SPSS statistics 20.0. A p-value of less than 0.05 was considered statistically significant.

RESULTS

The study involved 296 participants, with an average age of 41.84±15.76 years, ranging from 18 to 75 years. Approximately 30.3% of the participants were between the ages of 18 and 29. Of the total participants, 175 (59.1%) were female, with an average BMI of 23.66±4.10 kg/m², spanning from 12 to 33 kg/m². BMI values of 47.6% of the participants were in the normal range (Table 1).

Table 1. Cricothyroid membrane height of the study population according to age, gender, BMI and position

(n=296)	Mean±SD Median (Min-Max)	
Age group (year)	**41.84±15.76 42 (18-75)**	
18-29	90	30.3
30-39	48	16.2
40-49	57	19.3
50-59	49	16.6
≥60	52	17.6
Gender	**n**	**%**
Female	175	59.1
Male	121	40.9
BMI (kg/m²)	**23.66±4.10 24 (12-33)**	
	n	**%**
18.5	24	8.1
18.5-24.9	141	47.6
25-29.9	100	33.8
30	31	10.5
CTM height in neutral position (mm)	**6.98±0.66 6.6 (6.1-8.1)**	
CTM height in maximum extended position (mm)	**9.03±0.61 8.9 (7.9-10.0)**	

BMI: Body-mass index, SD: Standart deviation, Min: Minimum, Max: Maximum, n: Number, CTM: Cricothyroid membrane, mm: Milimetre,

The average CTM height in the neutral position was found to be 6.98±0.66 mm (range 6.1-8.1 mm). When measured in the maximum extended position, the average CTM height increased to 9.03±0.61 mm (range 7.9-10.0 mm). The measurements indicate that the CTM height in the maximum extended position was significantly higher than in the neutral position (p<0.001).

In the neutral position, the CTM height was significantly lower in females compared to males (p<0.001). This pattern was also observed in the maximum extended position, where the CTM height remained significantly lower for females compared to males (p<0.001) (Table 2).

The CTM height in the neutral and maximum extended positions interobserver correlations were 0.97 and 0.95, respectively.

DISCUSSION

The CTM is a pivotal anatomical landmark in emergency front-of-neck access procedures.[14] Effective airway management, particularly in emergency situations where conventional methods fail, hinges on accurate airway assessment. Cricothyrotomy serves as the definitive intervention in critical "cannot intubate, cannot oxygenate" scenarios.[2] To effectively perform cricothyrotomy, especially under urgent conditions, a thorough understanding of the relevant anatomical structures is crucial. USG has become indispensable for identifying key radiological features of the upper airway, establishing itself as the gold standard for on-the-spot identification and measurement of the CTM.[5,10] Our study specifically evaluated the variability in CTM height based on gender, age, and BMI in both neutral and maximally extended neck positions.

Our findings are contextualized by comparing them with prior research. Kelly et al.[14] measured the CTM height using computed tomography (CT) in patients aged 16-19 years, finding a strong correlation with age, with CTM heights ranging between 5.4 and 6.2 mm in male adolescents and 4.6 and 5.8 mm in female adolescents. Another research involving

Table 2. Cricothyroid membrane height in neutral and maximum extended position according to age, gender, and BMI

	CTM height in neutral position (mm)			CTM height in maximum extended position (mm)		
	Mean±SD	Median (min-max)	p	Mean±SD	Median (min-max)	p
Age group (year)						
18-29	6.99±0.66	6.6 (6.2-8.1)	0.899[b]	9.01±0.62	8.9 (7.9-10.0)	0.990[b]
30-39	6.96±0.67	6.6 (6.2-7.9)		9.05±0.59	8.8 (7.9-9.9)	
40-49	6.98±0.66	6.6 (6.2-7.9)		9.04±0.61	8.9 (7.9-9.9)	
50-59	6.96±0.66	6.6 (6.2-7.9)		9.01±0.62	8.8 (7.9-9.9)	
≥60	7.01±0.70	6.6 (6.1-7.9)		9.06±0.63	8.8 (7.9-9.9)	
Gender						
Female	6.45±0.17	6.4 (6.1-6.9)	<0.001[c]	8.57±0.30	8.7 (7.9-9.1)	<0.001[c]
Male	7.74±0.25	7.8 (6.3-8.1)		9.70±0.19	9.7 (8.6-10.0)	
BMI (kg/m²)						
18.5	6.88±0.68	6.5 (6.2-7.9)	0.260[b]	8.96±0.63	8.7 (8.2-9.9)	0.160[b]
18.5-24.9	6.92±0.64	6.6 (6.2-7.9)		8.98±0.60	8.8 (7.9-9.9)	
25-29.9	7.01±0.68	6.6 (6.1-8.1)		9.05±0.62	8.9 (7.9-10.0)	
30	7.21±0.69	7.7 (6.2-7.9)		9.25±0.61	9.6 (8.1-9.8)	

BMI: Body-mass index, mm: Milimetre, SD: Standart deviation, Min: Minimum, Max: Maximum, b: Kruskal Wallis variance analysis, c: Mann-Whitney u test, CTM: Cricothyroid membrane

15 adult cadavers reported mean CTM heights of 10.9 mm in males and 9.5 mm in females.[15] Additionally, Nutbeam et al.'s[7] study on 482 trauma patients reformatted from CT scans found the average CTM height to be 7.89 mm and 7.88 mm in male patients, and 6.00 mm and 5.92 mm in female patients. Their findings also indicated a gradual increase in CTM height from adolescence through the fourth decade, leveling off between the fourth and sixth decades, and subsequently decreasing with advancing age.

In our study, we observed notable differences in the height of the CTM across different neck positions neutral and maximum extension and these differences varied significantly by gender. However, no significant differences were detected across age groups. This lack of variation by age could be attributed to the demographic composition of our volunteer group, which predominantly consisted of younger individuals. Similarly, the absence of significant differences between BMI and CTM height measurements may be due to the limited number of participants with a higher BMI in our study sample.

In a study involving 50 pregnant women beyond 28 weeks of gestation, with an average age of 32.9 years and a BMI of 29.9, the median CTM height was found to be 10.3 mm in a neutral position and 11.7 mm when extended.[16] Another study examining 50 fresh adult autopsy cases (35 men and 15 women) with ages ranging from 17 to 83 years reported mean CTM heights of 6.57 mm for men and 5.80 mm for women.[17] Wong et al.[18] conducted USG on 39 adults, both with a rigid neck collar and in an extended neck position, and determined the average CTM length to be 10.5 mm. Research utilizing neck CT scans highlighted a decrease in CTM height in neutral positions among male patients older than 65.[7] In contrast, Dixit et al.'s[19] study with 22 volunteers found that extending the head and neck from the neutral position increased the CTM height by 2-3 mm, though no clear correlation with height, weight, or BMI was observed.

Our study echoes the literature, showing that the CTM height is greater in a maximally extended position compared to the neutral stance. This increase is likely due to the upward movement of the thyroid cartilage relative to the stationary carina, stretching the larynx and trachea and thus enlarging the space at the cricothyroid joint.[18,20]

In a prospective study conducted by Oliveira et al.,[21] six anesthesia trainees comprising four residents and two fellows participated in a focused 2-hour training session on neck ultrasound. This session was specifically designed to help identify neck landmarks and the CTM. Impressively, after just this brief training period, the majority of the trainees (n=4 out of 6) demonstrated proficiency in using ultrasound to identify the CTM, achieving this competence within an average of fewer than 20 scans and in less than 60 seconds. Furthermore, these skills were largely retained, with the trainees remaining competent three months later.

The ability to accurately locate the CTM is crucial for emergency doctors, especially given that the effectiveness of USG can significantly vary depending on the operator. Thus, a structured training and assessment program is essential to boost diagnostic precision. Our study supports the notion that USG, particularly in CTM assessment, is relatively straightforward to learn, as evidenced by a strong correlation between different observers. This ease of learning, combined with the widespread availability of ultrasound machines in emergency departments, underscores the necessity for all emergency physicians to be trained and encouraged to perform these scans effectively.[18]

Limitations

This study presents several limitations that warrant mention. First, individuals under 18 years of age were excluded, potentially affecting the generalizability of the findings across all age groups. Additionally, the majority of the volunteers were younger, and there was a notably low number of participants with a BMI.

CONCLUSION

The findings of this study underscore the variability in the height of the CTM across different genders and neck positions, emphasizing its clinical significance in performing cricothyrotomy. Particularly within the Turkish population, these variations highlight the necessity for tailored approaches in emergency airway management. The study demonstrates that gender-specific differences and the positioning of the neck critically influence CTM height, which can impact the success and safety of cricothyrotomy procedures. Moreover, this research contributes to a broader understanding of anatomical variability, which can aid clinicians in preparing for and executing emergency procedures more effectively. The implications of these findings are profound, suggesting that ongoing education and training in understanding anatomical diversity are crucial for emergency medical personnel.

Declaration of Patient Consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her consent for his/ her images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and that due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was carried out with the permission of Ankara Etlik City Hospital Clinical Researches Local Ethics Committee (Date: 06.03.2024, Decision No: 2024-204).

Informed Consent

All patients signed and free and informed consent form.

Referee Evaluation Process

Externally peer reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure
The authors declared that this study has received no financial support.

Author Contributions
All the authors declare that they have all participated in the design, execution, and analysis of the study and that they have approved the final version.

REFERENCES

1. Lin J, Bellinger R, Shedd A, et al. Point-of-care ultrasound in airway evaluation and management: a comprehensive review. *Diagnostics (Basel).* 2023;13(9):1541. doi: 10.3390/diagnostics13091541
2. Katayama A, Watanabe K, Tokumine J, et al. Cricothyroidotomy needle length is associated with posterior tracheal wall injury: a randomized crossover simulation study (CONSORT). *Medicine (Baltimore).* 2020;99(9):e19331. doi: 10.1097/MD.0000000000019331
3. Alerhand, S. Ultrasound for identifying the cricothyroid membrane prior to the anticipated difficult airway. *Am J Emerg Med.* 2018;36:2078-2084.
4. Suzuki K, Yambe N, Hojo K, Komatsu Y, Serikawa M, Usami A. Anatomical morphometry for cricothyrotomy puncture and incision. *BMC Surg.* 2023;23(1):198. doi: 10.1186/s12893-023-02100-9
5. Athanassoglou V, Hughes-Jones H, Hadjipavlou G, Teoh WH, Kristensen MS, Vanner R. Depth to the airway lumen at the level of the cricothyroid membrane measured by ultrasound. *Acta Anaesthesiol Scand*. 2020;64(1):48-52. doi: 10.1111/aas.13464
6. Altun D, Ali A, Koltka K, et al. Role of ultrasonography in determining the cricothyroid membrane localization in the predicted difficult airway. *Ulus Travma Acil Cerrahi Derg.* 2019; 25:355-360.
7. Nutbeam T, Clarke R, Luff T, Enki D, Gay D. The height of the cricothyroid membrane on computed tomography scans in trauma patients. *Anaesthesia.* 2017;72(8):987-992. doi: 10.1111/anae.13905
8. Goto T, Kishimoto T, Sakurai S. The effectiveness of educational methods for cricothyroid membrane identification by dental students: a prospective study using neck photographs and tracheotomy trainers. *Clin Exp Dent Res.* 2019;5(2):170-177. doi: 10.1002/cre2.167
9. McCaul CL, Bick E, Vanner R. Equipment for cricothyroidotomy: optimum tube size needs a compatible bougie. *Comment on Br J Anaesth*. 2021;127:479-486. *Br J Anaesth*. 2021;127(6):e191-e192. doi: 10.1016/j.bja.2021.09.001
10. Osman A, Sum KM. Role of upper airway ultrasound in airway management. *J Intensive Care*. 2016;4:52. doi: 10.1186/s40560-016-0174-z
11. Weir CB, Jan A. BMI classification percentile and cut off points. [Updated 2020 Jul10].In StatPearls. https://www.ncbi.nlm.nih.gov/books/NBK541070/ (StatPearls Publishing, 2020)
12. Kristensen MS, Teoh WH, Rudolph SS. Ultrasonographic identification of the cricothyroid membrane: best evidence, techniques, and clinical impact. *Br J Anaesth*. 2016;117(Suppl 1):i39-i48.
13. Kristensen MS, Teoh WH, Rudolph SS, Hesselfeldt R, Borglum J, Tvede MF. A randomised cross-over comparison of the transverse and longitudinal techniques for ultrasound-guided identification of the cricothyroid membrane in morbidly obese subjects. *Anaesthesia*. 2016; 71(6):675-683.
14. Kelly GS, Tekes-Brady A, Woltman NM. Anatomic characteristics of the adolescent cricothyroid membrane on computed tomography scans. *Pediatr Emerg Care*. 2022;38(9):e1533-e1537. doi: 10.1097/PEC.0000000000002622
15. Dover K, Howdieshell TR, Colborn GL. The dimensions and vascular anatomy of the cricothyroid membrane: relevance to emergent surgical airway access. *Clin Anat NYN.* 1996;9(5):291-295.
16. Wild E, You-Ten KE, Zasso F, Downey K, Ye XY, Siddiqui N. Impact of changing head and neck position on cricothyroid membrane localisation and height in third trimester parturients: an observational study. *Eur J Anaesthesiol*. 2022;39(6):566-568. doi: 10.1097/EJA.0000000000001564
17. .Prithishkumar IJ, David SS. Morphometric analysis and clinical application of the working dimensions of cricothyroid membrane in south Indian adults: with special relevance to surgical cricothyroidotomy. *Emerg Med Australas*. 2010;22(1):13-20.
18. Wong LY, Yang MLC, Leung HJ, Pak CS. Feasibility of sonographic access to the cricothyroid membrane in the presence of a rigid neck collar in healthy Chinese adults: a prospective cohort study. *Australas J Ultrasound Med*. 2019;23(2):121-128. doi: 10.1002/ajum.12187
19. Dixit A, Ramaswamy KK, Perera S, Sukumar V, Frerk C. Impact of change in head and neck position on ultrasound localisation of the cricothyroid membrane: an observational study. *Anaesthesia.* 2019;74(1):29-32.
20. McCaul CL, Bick E, Vanner R. Equipment for cricothyroidotomy: optimum tube size needs a compatible bougie. *Comment on Br J Anaesth.* 2021;127:479-486. *Br J Anaesth*. 2021;127(6):e191-e192. doi: 10.1016/j.bja.2021.09.001
21. Oliveira KF, Arzola C, Ye XY, Clivatti J, Siddiqui N, You-Ten KE. Determining the amount of training needed for competency of anesthesia trainees in ultrasonographic identification of the cricothyroid membrane. *BMC Anesthesiol*. 2017;17(1):74. doi: 10.1186/s12871-017-0366-7