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Surgical anatomy of cricothyroid membrane with reference to airway surgeries in North Indian population: a cadaveric study'

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ABSTRACT

Background: Surgical cricothyroidotomy is used to rapidly gain entry into the subglottic airway by creating an opening in cricothyroid membrane. The size and position of cricothyroid membrane is variable depending on racial characteristics of the individual. Statistics regarding dimensions of cricothyroid membrane has been documented extensively in Caucasian race. This study aims to augment the meagre information available on the Indian population on this important part of upper airway.

Methods: Morphometric cadaveric analysis done in tertiary health care centre. 39 adult human cadaveric larynges were obtained for this study. Using electronic Vernier caliper, different dimensions of cricothyroid membrane and depth of subglottis were noted down in predesigned proforma in standard office software. Data obtained was collated and compared with existing literature.

Results: The average dimensions of cricothyroid space and cricothyroid membrane were uniformly larger in males compared to females. Mean middle width F: 10.92±1.57 mm, M: 13.84±2.54 mm; mean height F: 7.26±1.82 mm, M: 9.61±1.86 mm; mean thickness F: 2.89±0.22 mm, M: 4.53±0.92 mm and mean subglottic depth F: 17.24±2.09 mm, M: 21.94±2.93 mm.

Conclusions: Inter specimen disparity was noted. As cricothyroid membrane is smaller in Indian population compared to Caucasian population, ET tubes size 3.0 to 5.0 in females and 4.0 to 6.0 in males are suggested for use for cricothyroidotomy. Oversized tubes are known to cause dysphonia, laryngeal damage and subglottic stenosis.

Keywords: Cricothyroid membrane, Cricothyroidotomy, Subglottis, Cadaveric study

INTRODUCTION

Cricothyroid space is the space that extends between the arch of the cricoid cartilage below and the inferior edge of the thyroid lamina above. The cricothyroid membrane covers this space between the cricoid and the thyroid, which on either side of the midline is occupied by the thicker median cricothyroid ligament. The cricothyroid space and membrane is easily accessible from the surface.

Although orotracheal intubation is the preferred method of securing the airway, many conditions demand establishing an urgent surgical airway. Surgical cricothyroidotomy is one such technique used to rapidly gain entry into the subglottic airway by creating an opening in the cricothyroid membrane. However, the size and position of the cricothyroid membrane is variable depending on racial characteristics of the individual. Statistics regarding the dimensions of the cricothyroid membrane has been documented extensively in the

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Caucasian race.^{2,3} Race, heredity, climate and nutritional status are known to affect the body size of a population.

More knowledge regarding the cricothyroid membrane in Indian population would facilitate optimal procedural guidelines for cricothyroidotomy in Indians.

Objective

The purpose of the current paper was to measure the dimensions of the cricothyroid membrane and the depth of subglottic space in the adult north Indian population.

METHODS

The study was performed at a university teaching hospital – Dept of ENT, Army College of Medical Sciences and associated Base Hospital, Delhi Cantt – 110010, from Jul 2016 to Mar 2018, on thirty nine (n=39) apparently normal adult Indian cadaveric larynges (F:M – 14:25) obtained from Dept of Anatomy, Army College of Medical Sciences, Delhi Cantt. Laryngeal specimens excised from cadavers with any possibilities of laryngeal damage as a result of diseases or manipulations were not taken into consideration.

All the larynges were removed from the hyoid till the second tracheal ring. All soft tissues (ligaments and muscles) were carefully removed. These larynges were serially numbered F-01 to F-14 for female specimens and M-01 to M-25 for male specimens. The cricothyroid membrane was identified in the space between the thyroid and cricoid cartilages, and the dimensions measured using an electronic vernier caliper (with least count of 0.1 mm), as shown in Figure 1. The findings were recorded in the predesigned proformas.



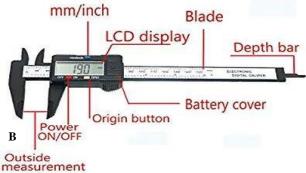


Figure 1 (A and B): Electronic digital caliper used in the study and its schematic representation.

The following measurements as shown in Figures $-2^4 & 3$ were taken:

- (a) Upper transverse width (just below the thyroid lamina)
- (b) Middle transverse width (at the midpoint of cricoid & thyroid)
- (c) Lower transverse width (just above the cricoid arch)
- (d) Height of the membrane (at the midline)
- (e) Thickness of the membrane
- (f) Depth of the subglottic space (at upper border of cricoid arch in midline, from its inner rim to the posterior wall of larynx)

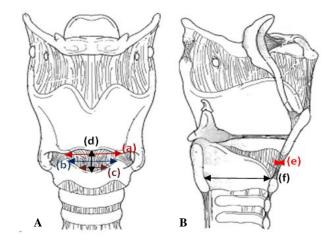


Figure 2 (A and B): Schematic diagram of dimensions of cricothyroid membrane measured in the study.⁴

(a) Upper transverse width (just below the thyroid lamina); (b) Middle transverse width (at the midpoint of cricoid & thyroid); (c) Lower transverse width (just above the cricoid arch); (d) Height of the membrane (at the midline); (e) Thickness of the membrane; (f) Depth of the subglottic space (at upper border of cricoid arch in midline, from its inner rim to the posterior wall of larynx)





Figure 3: Some of the measurements recorded using the caliper on the cricothyroid membrane. (A) Upper transverse width; (B) Height of the membrane.

The data obtained was finally entered into Microsoft Excel (Microsoft Corporation, Silicon Valley, Ca. USA) and analyzed. For each of the parameters, range (minimum value – maximum value), arithmetic mean and standard deviation (S.D.) were calculated.

RESULTS

Table 1: Dimensions of the cricothyroid membrane (females).

Parameter	Dimension (in mm)			
(n=14)	Range	Mean	Std dev.	
(a) Upper width	10.5 - 15.5	13.76	± 1.63	
(b) Middle width	6.8 - 12.9	10.92	± 1.57	
(c) Lower width	2.9 - 7.3	5.87	± 1.29	
(d) Height	5.8 - 9.4	7.26	± 1.82	
(e) Thickness	1.1 - 4.9	2.89	± 0.22	
(f) Depth (subglottis)	13.1 – 21.3	17.24	± 2.09	

The measurements of the various dimensions in female larynges (n=14) are shown in Table 1, while those of male specimens (n=25) are shown in Table 2. As can be seen from the data, the average dimensions of cricothyroid space and cricothyroid membrane were uniformly larger in males compared to females. The three measured widths [(a), (b) & (c)] were unvaryingly greater in males in contrast to females (range: upper width – F:

10.5-15.5 mm; M: 14.9-23.3 mm, middle width— F: 6.8-12.9 mm; M: 10.7-19.8 mm, lower width— F: 2.9-7.3 mm; M: 5.9-11.2 mm).

Table 2: Dimensions of the cricothyroid membrane (males).

Parameter	Dimension (in mm)			
(n=25)	Range	Mean	Std dev.	
(a) Upper width	14.9 - 23.3	18.67	±2.65	
(b) Middle width	10.7 - 19.8	13.84	±2.54	
(c) Lower width	5.9 - 11.2	8.12	±1.93	
(d) Height	7.7 - 11.7	9.61	±1.86	
(e) Thickness	2.3 - 7.9	4.53	±0.92	
(f) Depth (subglottis)	17.8 – 27.2	21.94	±2.93	

The height of the cricothyroid space in the midline was marginally larger in males (range– F: 5.8-9.4 mm; M: 7.7-11.7 mm). Similarly the thickness of the cricothyroid membrane was slightly smaller in females (range –F: 1.1-4.9 mm; M: 2.3-7.9 mm).

The depth of the subglottic larynx at the level of upper border of cricoid cartilage ranged from 13.1-21.3 mm in women and 17.8-27.2 mm in men. The depth of larynx was less in women in contrast to men.

Table 3: Comparison of dimensions (Western studies vs. Indian studies)

Dimension (in mm)	Dover et al ³	Dover et al ³ (n=15)		Prithishkumar et al ⁸ (n=50)		Current study (n=39)	
	Females	Males	Females	Males	Females	Males	
(a) Upper width*	9.5	11.6	8.66	11.38	13.76	18.67	
(b) Middle width*	6.9	8.8	6.11	8.36	10.92	13.84	
(c) Lower width*	3.5	4.5	2.83	3.69	5.87	8.12	
(d) Height	9.5	10.9	5.74	6.53	7.26	9.61	
(e) Thickness	-	-	2.70	3.54	2.89	4.53	
(f) Depth (subglottis)	-	-	15.62	20.73	17.24	21.94	

^{*&#}x27;Working' dimensions (exposed area of the membrane between the two cricothyroid muscles) were measured in the other two studies, whereas 'full' dimensions (complete widths) were measured in the current study.

DISCUSSION

In substantial neck swelling caused by subcutaneous oedema, haematoma or emphysema, emergency cricothyroidotomy is very complicated as normal anatomical landmarks are obliterated. Blind attempts have frequently caused injury to the thyroid cartilage, accidental penetration of thyrohyoid membrane or tracheal insertion of the airway. Puncture of the posterior wall of larynx and oesophagus are reported as well following cricothyroidotomy. Fatal airway hemorrhage has also been reported following cricothyroidtomy resulting in endobronchial hemorrhage and asphyxia.

Placing outsized tubes results in fracture of the laryngeal cartilages and later dysphonia and subglottic stenosis. ^{2,5-7} Hence a thorough understanding of the dimensions of the cricothyroid membrane is vital to prevent such complications, especially in relevance to the population we serve. The present study on 39 adult laryngeal specimens (25 male and 14 female) focuses entirely on the Indian race (north Indian subset).

Table 3 compares the dimensions in the subjects of the present study with the working dimensions of the article by Dover et al that dealt with Caucasian subjects and working dimensions of the article by Prithishkumar et al done with south Indian subjects.^{3,8} It is to be noted that

although the previous studies take into account 'working dimension' meaning the exposed cricothyroid membrane (between the two cricothyroid muscles), this study measures the entire membrane that is available in the cricothyroid space, as we feel the entire space is available for cricothyroidotomy should the need arise. It is observed that the dimensions are consistently smaller in the adult Indian population compared with their Caucasian counterparts, and almost comparable between the north and south Indian population. Tube sizes recommended in studies with Caucasian subjects might not be applicable to Indian population. Further there is minor variation in dimensions between the north and south Indian population.

Cannula with dimensions of outer diameter 8 mm and internal diameter of at least 5 mm has been suggested by The American Association of Clinical Anatomists for use in cricothyroidotomy.9 Smaller cannulas are easier to introduce, but narrower the tube more is the resistance to airflow, as per Poiseuille's law. Although it is quicker to insert a smaller diameter cannula, more reliable oxygenation († PaO₂) was attained only with larger cannulas. 10 Narrod et al has recommended size 6 tracheostomy tube (which has an internal diameter of 6 mm and an outer diameter of 8 mm) for cricothyroidotomy. Larger cannulas might fracture the thyroid or cricoid cartilage and also cause subglottic stenosis.^{2,5-7} Dover et al cautioned that tubes frequently utilized for tracheostomy (#8 and #10 Shiley tracheostomy tubes with outer diameters of 12 mm and 13 mm respectively) could cause laryngeal injury when used for cricothyroidotomy.³

Develi et al established that the vital anatomical structures (cricothyroid vessels, pyramidal lobe of thyroid gland) were mostly located on the upper half and lower left quadrant of the cricothyroid membrane. They further recommend that the lower right quadrant of the membrane is safer for invasive procedures such as needle cricothyroidotomy or other cannulation techniques.

Perforation of the posterior wall of larynx and oesophagus are reported complications following cricothyroidotomy resulting in the formation of tracheoesophageal fistulae.^{3,12} This study showed that depth of subglottic larynx ranged from 13.1 to 27.2 mm; with mean being 17.24±2.09 mm in women and 21.94±2.93 mm in men. Care should be taken not to incise too deeply while entering the subglottic larynx.

CONCLUSION

When rapid surgical access to the airway is required following traumatic injury, cricothyroidotomy is the procedure of choice. To avoid or manage complications following surgical cricothyroidotomy, understanding of the dimensions and relations of the cricothyroid membrane is crucial.

As dimension of the cricothyroid membrane is smaller in the Indian population compared to Caucasian population, ET tubes ranging from size 3.0 to 5.0 in females and size 4.0 to 6.0 in males are suggested for use for cricothyroidotomy in north Indian population. Insertion of oversized tubes is known to cause dysphonia, laryngeal damage and subglottic stenosis. There is scope for additional research to corroborate these findings and study if there is any disparity in size in other ethnic races in the world.

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