Original Article

Morphometry of adult cricoid cartilage in Nepalese cadavers: a cross-sectional observational study

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ABSTRACT

Background: Cricoid cartilage is crucial during endotracheal intubation, yet its dimensions in the Nepali population remain uncharacterized. This study aimed to measure cricoid cartilage dimensions in adult Nepalese.

Methods: A total of 105 cadavers (75 males, 30 females) were dissected at Department of Forensic Medicine, Maharajgunj Medical Campus, Nepal. Measurements of outer and inner transverse and anteroposterior diameters, as well as heights of the cricoid arch and lamina, were taken using digital vernier callipers. Statistical analyses included gender comparisons and correlations with age.

Results: The mean age of the 105 cadavers studied was 34.11 years (SD = 12.08). The measurements of outer anteroposterior diameter, outer transverse diameter, inner anteroposterior diameter, inner transverse diameter, arch height and lamina height were respectively 22mm (SD=4), 21mm (SD=4), 18mm (SD=3), 17mm (SD=3), 9mm (SD=3) and 24mm (SD=4). Inner AP ($p = 0.009$) and inner TR ($p = 0.021$) measurements correlated significantly with age. Males had significantly larger cricoid cartilage dimensions than females ($p < 0.001$).

Conclusions: This study provided essential data for selecting appropriately sized ETTs in Nepalese patients, reducing airway complications. It underscored the need to tailor medical devices to local anatomical variations, supporting advancements in biomechanical modelling and medical research.

Keywords: Cricoid cartilage, Nepalese population, endotracheal tube sizing, airway management, anatomical variations.

Article Information

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INTRODUCTION

Securing the airway is a critical aspect of lifesaving interventions, a fact that has been well-established[1]. A fundamental understanding of the anatomy of larynx is essential from a clinical perspective. This knowledge is crucial for professionals involved in the surgical treatment of the larynx, including speech therapists, anesthesiologists, oncologists, pulmonologists, radiologists, general practitioners, otorhinolaryngologists, and phoniatricians[2]. It is also necessary for procedures such as transplantation, stenting, intubation, cricothyroidotomy, and endoscopic interventions[3]. Detailed data on endolaryngeal angles, airway lumina, and the thickness of parts of the laryngeal skeleton can significantly aid in planning endolaryngeal surgical interventions[4].

Among the various cartilages of the larynx, the cricoid cartilage is unique as the only supporting element that extends completely around the airway[1]. It is the lowest of the laryngeal cartilages and serves as the

foundational structure of the larynx, featuring a narrow anterior arch and a broad posterior lamina[5]. Shaped like a signet ring, the cricoid cartilage is horizontally oriented with the narrow part of the ring anteriorly. It is smaller but thicker and stronger than the thyroid cartilage[6]. The cricoid cartilage attaches to the inferior margin of the thyroid cartilage via the median cricothyroid ligament and to the first tracheal ring via the cricotracheal ligament[7]. The lateral surface of the cricoid cartilage has facets for articulation with the inferior cornu of the thyroid cartilage and the arytenoid cartilage[8]. The internal surface of the cricoid cartilage is smooth and lined by mucosa. Being a hyaline cartilage, the cricoid is prone to calcification and ossification with age[9].

Given its crucial role in airway management and surgical interventions, a detailed morphometric analysis of the cricoid cartilage is essential. This study aims to observe and construct the morphometric data of the human cricoid cartilage in adult Nepalese cadavers. Specifically, it will measure the inner and outer anteroposterior (AP) and transverse (TR) diameters of the cricoid cartilage, as well as the height of its arch and lamina, correlate these measurements, and compare them between male and female cadavers. This data will provide valuable insights for clinical and surgical practices involving the larynx.

METHODS

This observational (descriptive) cross-sectional study was conducted at the Department of Forensic Medicine and Toxicology, Maharajgunj Medical Campus from December 2016 to May 2017 after ethical clearance from Institutional Review Board, Institute of Medicine (Approval number: "182(6-11-E)^2/073/074"). Cadavers from road traffic accidents without neck injury, poisoning, bullet injuries, burns or myocardial infarction and those with intact air passages, and adult (18 years and above) Nepalese nationals were included in the study. Out of 1600 cases screened, 800 met the aforementioned criteria for the study. A total of 105 cadavers (male and female) were selected by purposive sampling after excluding cases of death by strangulation, suffocation, laryngeal diseases, putrefied cadavers, aviation injuries, and pediatric cases.

The study utilized dissecting forceps and scalpel for dissecting out and cleaning cricoid cartilages, digital sliding Vernier calipers, and a flexible measuring tape for measurements (figure 1).

Variables measured included the external and internal diameters of the cricoid cartilage in anteroposterior and transverse axes, as well as the height of the cricoid arch and lamina after removing all soft tissues (figure 2).

Data thus obtained was recorded in a pro forma, and entered into computer in Microsoft Excel software. Further analysis was done in SPSS version 18. Comparison of diameters among gender was done by independent samples t-test and correlation of measurements with age was done using Pearson's correlation test.

Figure 1: Cricoid cartilage dissected, cleaned and being measured for the study.

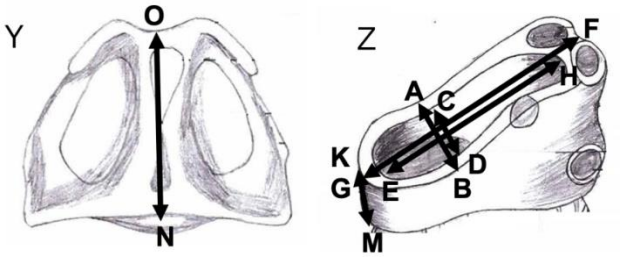

Figure 2: Illustration drawn by principal investigator to show measurements of cricoid cartilage taken for the study. Y = Posterior view, Z = anterolateral view, N-O= height of lamina, A-B= Outer TR, C-D= Inner TR, E-H= Inner AP, G-F= Outer AP, K-M= Arch height. Adapted from Gray's Anatomy (Standring et al.)[1].

RESULTS

In this study, 105 Nepalese cadavers (75 males and 30 females) were studied. All cadavers belonged to 18 to 60 years of age group with mean age of 34.11 years (standard deviation = 12.08). Mean age of male cadavers was 35.2 years (standard deviation = 12.60) while that of female cadavers was 31.40 years (standard deviation = 10.36). The distribution of male and female population is shown in figure 3.

The average outer AP diameter of cricoid ranged from 15 to 36 mm while the inner AP diameter ranged from 10 to 26 mm. Similarly, the outer transverse diameter ranged from 14 to 40 mm while the inner transverse diameter ranged from 10 to 22 mm. The arch height ranged from 4 to 18 mm and the lamina height ranged from 15 to 33 mm. The mean and standard deviation of measurements of cricoid cartilage along with comparison among male and female are shown in table 1.

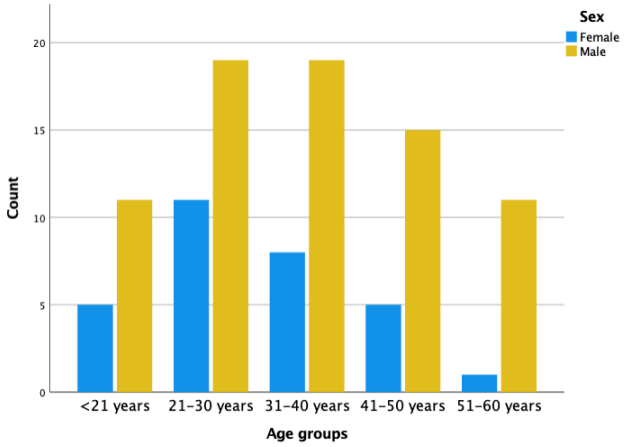

Figure 3: Clustered bar diagram showing age distribution of male and female population. (n=105)

Table 1: Different measurements of cricoid cartilage in the study population. All measurements are in mm. df = degrees of freedom. (*= significantly higher measurements in male)

Measurements	Female		Male		Both		Independent samples t-test		
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	t	df	p-value*
Outer AP	18	3	23	3	22	4	8.56	70.896	<0.001
Outer TR	18	2	22	3	21	4	6.59	103	<0.001
Inner AP	15	2	19	3	18	3	7.24	103	<0.001
Inner TR	15	2	17	2	17	3	5.70	103	<0.001
Arch height	8	3	10	3	9	3	4.20	103	<0.001
Lamina height	21	3	26	3	24	4	7.72	103	<0.001

Pearson's correlation coefficient was calculated to correlate age with dimensions of cricoid cartilage. However, only the measurements of inner anteroposterior diameter and inner transverse diameter correlated significantly with age of the cadavers (figure 4). The coefficient of correlation of age to inner anteroposterior diameter was 0.254 (p-value = 0.009) and the coefficient of correlation of age to inner transverse diameter was 0.226 (p-value = 0.021).

DISCUSSION

The current study was a cross-sectional cadaveric study conducted at a tertiary care center using standard dissection and measurement procedures. Inter observer bias was eliminated as the principal investigator collected all the data and each measurement was taken three times and averaged before entry. However, the study was limited due to exclusion of pediatric population and also because of the smaller sample size.

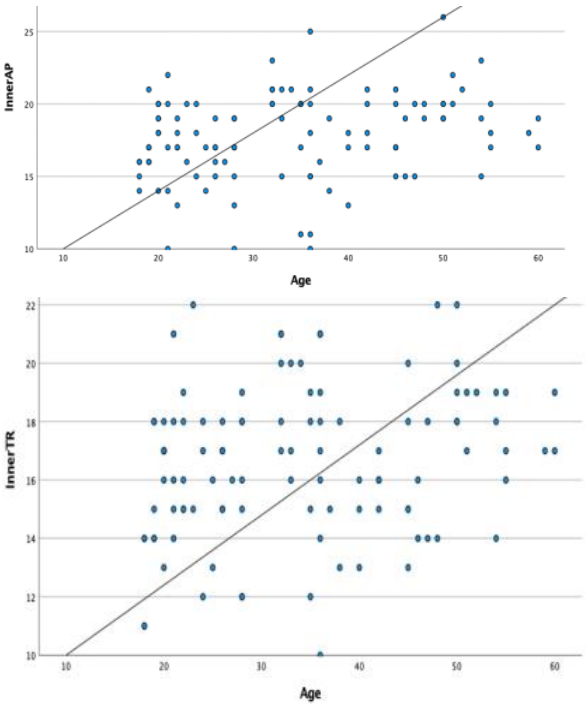

Figure 4: Scatterplot showing correlation between inner anteroposterior diameter (mm) and age (years), and inner transverse diameter (mm) and age (years).

The measurements in the present study were comparable to those in Northern and Western Indian populations[10,11], likely due to geographic proximity, similar dietary habits, and genetic makeup. However, the measurements were lower than those reported for Nigerian, German, and American populations, possibly due to racial variations[12–14]. The mean outer transverse diameter was consistent with earlier studies by Jain and Dhall and Singla RK[11,15].

The mean inner transverse diameter was lower than those found in Nigerian, German, and European populations but similar to the Indian population[13,14]. While our values are consistent with Indian studies, the disparity with Nigerian and German populations was seen likely due to racial differences. Both the height of the cricoid arch and the height of the lamina in our population were smaller compared to Nigerian, German, and American populations, suggesting ethnic and racial variations.

The comparison of different measurements among different populations is shown in table 2.

Table 2: Comparison of mean ± standard deviation among different studies including current study. All measurements are in mm.

Study	Sex	Transverse diameter		AP diameter		Height	
		Outer	Inner	Outer	Inner	Arch	Lamina
Ajmani (Nigerians)[13]	Male	-	29.84± 6.10	-	28.82± 4.07	8.35± 4.80	26.50± 6.30
	Female	-	25.84± 3.48	-	24.06± 2.53	7.5± 4.25	24.6± 5.32
Eckel (Germans)[14]	Male	-	26.4± 2.4	-	30.9± 3.06	6.9± 1.35	24.6± 1.84
	Female	-	21.4± 2.04	-	25.20± 2.33	6.20± 1.11	21.3± 1.44
Jain & Dhall (Indians)[15]	Male	25.7± 3.2	17.2± 3.6	28.6± 4.9	19.5± 2.5	6± 0.8	22± 1.9
	Female	21.3± 4.7	15.7± 4.4	23.2± 4.1	16.5± 5.0	5.6± 1	19± 2.3
Kaur (Indians)[11]	Male	24.77± 3.43	12.99± 2.38	20.01± 3.8	13.69± 3.1	7.56± 1.15	21.81± 2.93
	Female	21.94± 0.52	9.12± 1.38	19.89± 1.41	13.62± 2.9	7± 0.53	18.55± 0.65
Maue & Dickson (North America)[12]	Male	-	-	-	16.03	3.1	24.53
	Female	-	-	-	16.43	3.14	19.13
IK Sung (Korea)[16]	Male	-	-	-	-	7.10	22.3
	Female	-	-	-	-	5.72	20.1
Current study (Nepalese)	Male	22.25± 3.47	17.4± 2.46	23.40± 3.45	18.83± 2.5	9.97± 2.63	25.84± 3.18
	Female	17.70± 2.35	14.6± 1.71	18.1± 2.59	14.97± 2.38	7.60± 2.58	20.7± 2.80

In the current study, all dimensions of the cricoid cartilage, including inner and outer anteroposterior and transverse diameters, as well as the heights of the arch and lamina were found to be greater in males compared to females. This finding aligns with previous studies conducted on Nigerian, German, Indian, and Korean populations[12–14,16].

Although only inner anteroposterior diameter and inner transverse diameters increased significantly with increasing age in the current study, other studies in India showed increase of all dimensions with age[17]. A study in the Chinese population showed decrease in cricoid dimensions with increasing age[18]. However, it was a study done in CT scan measurements and results could not be compared well with the current study.

Although this is a first cadaveric study of the cricoid cartilage from Nepal, a larger sample size would enhance the representativeness of our findings within the whole population. Future studies should aim for a balanced representation of males and females to better elucidate mean differences in cricoid cartilage dimensions. Including pediatric populations in future studies could provide valuable insights into age-related variations. Additionally, considering ethnicity and race in further analysis would offer a more comprehensive understanding of these dimensions across different populations. Incorporating radiological studies to compare with cadaveric measurements would also strengthen the validity and applicability of our findings in clinical settings.

CONCLUSION

In this study, we examined cricoid cartilage dimensions in adult Nepalese, finding larger outer and inner diameters in males versus females, consistent with global trends. Our findings underscore the importance of considering both outer and inner dimensions in medical device design. Current endotracheal tubes (6.5-7 mm) suit Nepalese inner diameters (14-18 mm), reducing airway trauma risk. Our data also support biomechanical modeling and airway cast studies in medical research, aiding advancements in patient care across specialties.

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Literature search: DS, BA, MD
Data collection: DS
Data analysis: BA
Data Interpretation: DS, BA, MD, NR
Drafting and Reviewing of the manuscript for important intellectual content: DS, BA, MD, NR
Final approval of the version ready for submission: DS, BA, MD, NR
Agreement to be accountable for all aspects of the work: DS, BA, MD, NR

Ethical Approval: This research was approved by IRB of Institute of Medicine, Tribhuvan University, with the reference number of 182(6-11-E)^2/073/074 on 16th November, 2016.

Consent/Assent: Informed written consent was obtained from close relatives of all the deceased participants before data collection.

Data Availability Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request

Conflicts of Interest: Author(s) declare no conflict of interest

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