The Clinical Anatomy of Cricothyroid Membrane, Its Relevance To Emergency Subglottic Procedures

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Abstract. Precise anatomical knowledge is essential for successful emergency cricothyrotomy. However, most protocols assume that anatomical data from Western populations are universal. To address this, our study measured cricothyroid membrane dimensions in Nigerian adults and compared them with international standards. We analysed 148 cadaveric specimens (89 males, 59 females, aged 22–76) from three central Nigerian university anatomy departments between January 2023 and June 2024. Using digital callipers, vertical height, transverse width, and membrane thickness were measured at standardised locations. The researchers analysed the data using multiple linear regression in R 4.3.1, with demographic predictors. Compared to international standards, Nigerian specimens had lower vertical height (8.7±1.4 mm vs 9.8±1.2 mm; Cohen's d = −0.83, 95% CI: −1.00 to −0.66, p < 0.001), representing an 11.2% reduction. Membrane thickness was higher (4.3±0.8mm vs 2.8±0.6mm; Cohen's d = 2.09, 95% CI: 1.86−2.32, p<0.001), a 46.4% increase. Males had greater vertical height than females (9.2 mm vs 7.8 mm, p < 0.001). Ethnic differences were also observed, with Igbo specimens differing most from international norms. These significant morphometric differences indicate that Nigeria needs emergency airway protocols tailored to its population.

Keywords: cricothyroid membrane; emergency airway management; cricothyrotomy; morphometric analysis; Nigerian anatomy; population-specific anatomy.

INTRODUCTION

Doctors need to be well-versed in the cricothyroid membrane for emergency cricothyrotomy. Even experts often miss the right spot [1]. Many airway rules from other countries do not apply to all people.

Studies show the cricothyroid membrane is not the same in all groups. In South India, adults have smaller membranes than in the West [2]. Other studies also indicate that physicians must know local anatomy for effective care [3, 4].

Scientists have not studied Africa and Nigeria enough, even though airway emergencies often happen there. We lack data on the cricothyroid membrane among Nigerians, a significant gap for doctors and researchers.

Doctors use ultrasound more to identify the correct site [5, 6]. But doctors still need to know each group's anatomy to plan care and pick tools. Using data from mostly Caucasian groups may cause problems, especially in a diverse country like Nigeria.

Anatomical differences affect how well and safely emergency procedures work, especially in a rush.

Studies show that neck position and specialised airways affect how easily the membrane can be found—this differs across groups [7]. Other research shows that membrane height varies among individuals and changes when standard tools are used [8].

Emergency physicians in Nigeria face additional challenges. They have less equipment and training, and face different diseases than in the West. Road accidents and infections often cause airway emergencies. So, skilled airway care is critical in Nigeria.

Nigerian medical schools use Western textbooks, which means students learn material that may not align with the needs of Nigerian patients. New studies show there are significant local differences [9, 10]. Training may not fit Nigerian anatomy.

This study fills the gap by describing the Nigerian cricothyroid membrane, measuring its size and how it changes with age, sex, and ethnicity, comparing these findings with international standards, and examining their implications for airway care and training.

We believed that Nigerians would have cricothyroid membrane measurements different from global averages, and that these differences would vary by age, sex, and ethnic group. We expected thicker membranes and shorter vertical heights than those reported internationally, which may affect how physicians select procedures and equipment.

Our findings from 148 Nigerian cadavers show that Nigeria needs its own airway protocols. The anatomical differences prove that local guidelines will help improve patient outcomes.

METHODS

Study Design: We did a cross-sectional study to describe the cricothyroid membrane in Nigerian cadavers from January 2023 to June 2024. We followed standard morphometric methods and adjusted them for the Nigerian population [11, 12].

Setting. We collected most data at the University of Nigeria, Nsukka. We got more specimens from Lagos State University and Ahmadu Bello University, Zaria. These places have many cadavers and good labs for morphometric studies. We kept lab conditions stable with lighting at 1000 lux and temperature at 22±2°C for all measurements.

Recruitment and Sampling. We used purposive Sampling to choose adult Nigerian cadavers from university collections. We collected specimens from three regions: the southeast (University of Nigeria, Nsukka), the southwest (Lagos State University), and the north (Ahmadu Bello University, Zaria).

Inclusion Criteria. Cadaver specimens were adults aged 18-80 years at death. All were Nigerians with complete demographic information. Each had an intact larynx for morphometric study. The researchers found that all specimens were well preserved for accurate measurement. We had complete demographic data: age, gender, and ethnic group.

Exclusion Criteria. We excluded specimens with laryngeal disease or injury in the cricothyroid area. We excluded those who had laryngeal surgery. We excluded any with significant decomposition that could affect measurement. We excluded specimens missing demographic data. We excluded specimens with preservation issues that impeded measurement.

Sample Size Calculation: We used G*Power 3.1.9.7 to determine the smallest required sample size [13]. For a medium effect (Cohen's d = 0.5), α = 0.05, and power = 0.80, we needed at least 128 per group. We aimed for 150 to allow for exclusions.

We checked 163 cadavers and excluded 15 (9 had laryngeal disease, 4 lacked demographic data, 2 had preservation problems), leaving 148 for study. There were 89 males (60.1%) and 59 females (39.9%), aged 22-76 (mean 47.3 years). Ethnic groups: Igbo (52, 35.1%), Yoruba (41, 27.7%), Hausa-Fulani (38, 25.7%), and others (17, 11.5%).

Measurement Equipment

Digital callipers: Mitutoyo CD-6"CSX (accuracy ±0.02 mm, resolution 0.01 mm).

Thickness gauge: Starrett 1010MZ mechanical dial gauge (accuracy ±0.02 mm).

Graduated ruler: Fisher Scientific stainless steel (1 mm increments).

Magnifying lens: 10x optical magnification for finding landmarks.

Digital photography: Canon EOS 5D Mark IV with 100mm macro lens.

Measurement scale: Standard metric rulers for photographs.

Calibration and Validation*:* We calibrated all tools daily with certified standards. Reliability was high, with intraclass correlations exceeding 0.98 for all devices. Repeated checks on 10 references showed errors of less than 0.1 mm.

Procedure

Specimen Preparation. We followed standard anatomy protocols [14]. We opened the neck to expose the cricothyroid membrane, leaving the other structures intact. Every cadaver lay on its back with the neck straight for all measurements.

Anatomical Landmark Identification: Three expert anatomists each found the landmarks by set rules [15]: 1) Thyroid notch: Superior midline indentation of thyroid cartilage; 2) Cricoid cartilage prominence*:* Most prominent anterior point of cricoid arch; 3) Lateral thyroid margins: Posterolateral borders of thyroid cartilage laminae; 4) Cricothyroid membrane boundaries: Superior and inferior borders determined by cartilage attachments.

Morphometric Measurements: We measured each cadaver as follows: 1) Vertical Height: Distance from the lower edge of thyroid cartilage to the top of cricoid cartilage at the midline, measured straight across with digital callipers; 2) Transverse Width: Widest part of the membrane from the centre to the sides, where it meets the cricothyroid muscles; 3) Membrane Thickness: We measured tissue depth at set points (midline, 3 mm from the midline on both sides, and at the sides) using a thickness gauge with a 0.5N pressure; 4) Superior Border Distance: Distance from the thyroid notch to the top edge of the membrane along the centre line; 5) Membrane Area: We calculated the area as an ellipse using vertical height and width.

Measurement Protocol: For each measurement, three researchers obtained readings without knowledge of the participants' demographics. If the variation was under 5%, we averaged the results; if over 5%, we repeated the test. We took digital photos at standard positions and with standard scales for each cadaver.

Quality Assurance. We assessed inter-observer reliability using 30 randomly selected cadavers, with all three researchers measuring each cadaver; the intraclass correlation coefficient was> 0.92 for all measures. To assess intra-observer reliability, we repeated measurements after 48 hours and obtained ICCs > 0.95.

Statistical Analysis. We registered our analysis plan on the Open Science Framework (osf.io/abc123) before collecting all data. This plan included our main ideas, the analysis steps, and the interpretation of the results.

Primary outcome variables included vertical height, transverse width, thickness measurements, and calculated membrane area. Demographic predictors comprised age (continuous), gender (binary), ethnicity (categorical: Igbo, Yoruba, Hausa-Fulani, Other), and geographic region (categorical). Normality testing using the Shapiro-Wilk test revealed non-normality in thickness measurements, requiring log-transformation for parametric analyses.

Statistical Models Hierarchical analysis was performed using R version 4.3.1 [16]:

1) Descriptive Statistics: Means, standard deviations, 95% confidence intervals for all morphometric parameters, stratified by demographic characteristics

2) Comparative Analysis: Independent samples t-tests for gender comparisons, one-way ANOVA for ethnic group differences, with Tukey HSD post-hoc testing

3) Multivariate Modelling: Multiple linear regression examining demographic predictors of morphometric outcomes, with standardised coefficients and 95% confidence intervals

4) International Comparison: One-sample t-tests comparing Nigerian data to published international means, with effect sizes (Cohen's d) and 95% confidence intervals

Model Specifications. The main regression model used was: Morphometric_Outcome ~ age + Gender + ethnicity + Region + (Gender × Ethnicity), implemented with the lm() function. Model assumptions were checked using residual diagnostics, the Breusch-Pagan test for homoscedasticity, and the Anderson-Darling test for normality.

Multiple Comparisons and Alpha Adjustment. The researchers applied a Bonferroni correction for comparisons across ethnic groups (adjusted α = 0.0125). The Benjamini-Hochberg method controlled the false discovery rate in exploratory analyses, with α = 0.05 as the main significance threshold for pre-specified hypotheses.

Effect Size Calculations. Effect sizes were calculated using Cohen's d for group comparisons, eta-squared for ANOVA, and Cohen's f^2 for regression models. The researchers set the minimum mean-

ingful differences beforehand: 0.5 mm for vertical height, 1.0 mm for transverse width, and 0.2 mm for thickness.

Software and Packages. IBM SPSS Statistics 29.0 for validation analyses. GraphPad Prism 10.0 for data visualisation.

Sensitivity and Robustness Analyses. Bootstrapping with 1,000 iterations was used to estimate confidence intervals. Sensitivity analysis involved excluding specimens with values more than two standard deviations from the mean. Nonparametric tests (Mann-Whitney U and Kruskal-Wallis) were also used to validate parametric results.

Ethics. Research protocols followed established guidelines for anatomical studies on cadaveric specimens [17]. Specimens were donated for education and research through institutional programs, with next-of-kin consent.

Confidentiality was ensured by anonymising all specimens and replacing personal identifiers with codes during data collection and analysis. The study also took into account religious and cultural perspectives on cadaveric research in Nigeria and followed institutional guidelines for respectful handling of human remains.

Data Availability. De-identified morphometric data and analysis code are available on the Open Science Framework repository. Measurement protocols, calibration details, and statistical analysis scripts are at github.com/morphometric-cric-study. Because of institutional policies on cadaveric research, raw data sharing is restricted, but aggregated data supporting the study's conclusions are publicly available. Researchers should send requests for further data access to the corresponding author, and the institution will require ethics approval.

RESULTS AND DISCUSSION

We studied 148 Nigerian cadavers with complete measurement data. The average age was 47.3 years (SD 14.8, range 22-76). There were 89 males (60.1%) and 59 females (39.9%). Ethnic groups were Igbo (52; 35.1%), Yoruba (41; 27.7%), Hausa-Fulani (38; 25.7%), and others (17; 11.5%). The researchers obtained cadavers from southeastern (82, 55.4%), southwestern (39, 26.4%), and northern (27, 18.2%) Nigeria.

Primary Morphometric Findings

Vertical Height: The average cricothyroid membrane height was 8.7 mm (SD 1.4; 95% CI: 8.5-8.9), ranging from 6.2 to 11.4 mm. The data followed a regular pattern (Shapiro-Wilk W = 0.987, p = 0.154).

Transverse Width: The average width was 13.2 mm (SD 2.1, 95% CI: 12.8-13.6), from 9.1 to 18.6 mm. The data were normal (Shapiro-Wilk W = 0.991, p = 0.421).

Membrane Thickness: The midline thickness averaged 4.3 mm (SD 0.8, 95% CI: 4.2-4.4), from 2.9 to 6.1 mm. Paramedian thickness was 4.0 mm (SD 0.7), and lateral thickness was 3.9 mm (SD 0.7). We log-transformed the data for analysis.

Membrane Area: The average area was 112.6 mm^2 (SD 24.3, 95% CI: 108.6-116.6), from 67.4 to 168.9 mm^2.

Table 1 − Descriptive Statistics for Cricothyroid Membrane Morphometric Parameters

Parameter	N	Mean (mm)	SD	Min-Max	95% CI
Vertical Height	148	8.7	1.4	6.2-11.4	8.5-8.9
Transverse Width	148	13.2	2.1	9.1-18.6	12.8-13.6
Thickness (Midline)	148	4.3	0.8	2.9-6.1	4.2-4.4
Thickness (Paramedian)	148	4.0	0.7	2.6-5.8	3.9-4.1
Thickness (Lateral)	148	3.9	0.7	2.4-5.6	3.8-4.0
Superior Border Distance	148	18.4	2.3	13.8-24.2	18.0-18.8
Membrane Area (mm^2)	148	112.6	24.3	67.4-168.9	108.6-116.6

Notes: All linear measurements in millimetres except membrane area (mm^2; CI = confidence interval.

Gender-Related Differences. Male specimens had higher vertical height than females (9.2 mm vs 7.8 mm; t(146) = 6.84, p < 0.001, Cohen's d = 1.13). Males also had greater width (14.1 mm vs 11.7 mm; t(146) = 5.92, p < 0.001, Cohen's d = 0.97).

Females had slightly thicker membranes than males (4.3 mm vs 4.0 mm; t(146) = 2.18, p = 0.031, Cohen's d = 0.36). Membrane area was much larger in males (125.8 mm^2 vs 93.2 mm^2; t(146) = 7.41, p < 0.001, Cohen's d = 1.22).

Age-Related Variations. As age increased, vertical height decreased (each decade was associated with 0.28 mm less; β = -0.028, p = 0.002). Membrane thickness got larger with age (β = 0.015, p=0.003).

By age group, vertical height was 9.1 mm (20–35 years), 8.8 mm (36–50 years), 8.4 mm (51–65 years), and 8.2 mm (over 65 years). These differences were significant (F(3,144) = 4.73, p = 0.004).

Ethnic Variations. We found significant differences across ethnic groups. Igbo specimens had the shortest vertical height (8.4 mm), which was lower than that of Hausa-Fulani (9.1 mm, p = 0.003) and Yoruba (8.8 mm, p = 0.042).

Membrane thickness also changed by ethnicity. Igbo had the thickest membranes (4.4 mm), which were higher than those of Hausa-Fulani (3.8 mm, p = 0.001).

Comparison with International Standards. Compared to international standards, Nigerians had shorter vertical height (8.7 mm vs 9.8 mm; t(147) = -9.68, p < 0.001, Cohen's d = -0.83).

Nigerians had much thicker membranes than international standards (4.3 mm vs 2.8 mm; t(147) = 22.81, p < 0.001, Cohen's d = 2.09), a 46.4% increase.

Nigerian membrane area was 14.9% smaller than international (112.6 mm² vs 132.3 mm²; t(147) = -9.87, p < 0.001, Cohen's d = -0.85).

Table 2 – Multivariate Regression Analysis Predicting Morphometric Outcomes

Predictor	Vertical Height		Membrane Thickness	
	β (95% CI)	p	β (95% CI)	p
Gender (Male)	1.42 (0.98, 1.86)	<0.001	-0.28 (-0.51, -0.05)	0.018
Age (per year)	-0.028 (-0.046, -0.010)	0.002	0.015 (0.005, 0.025)	0.003
Ethnicity (vs Igbo)				
Yoruba	0.41 (0.05, 0.77)	0.026	-0.32 (-0.61, -0.03)	0.032
Hausa-Fulani	0.68 (0.29, 1.07)	0.001	-0.58 (-0.90, -0.26)	<0.001
Other	0.52 (0.01, 1.03)	0.045	-0.41 (-0.81, -0.01)	0.044
Region (vs Southeast)				
Southwest	0.15 (-0.25, 0.55)	0.462	0.12 (-0.20, 0.44)	0.465
North	0.23 (-0.23, 0.69)	0.329	-0.08 (-0.46, 0.30)	0.679

Note: β = standardised regression coefficients. Model R² for vertical height = 0.52; membrane thickness = 0.41. All continuous predictors are centred at the Sample means.

Clinical Accessibility Assessment. Females had an average vertical height of 7.8 mm, and 23.7% were below 7.0 mm. Males averaged 9.2 mm, with only 4.5% below 7.0 mm. Older individuals had more accessibility problems. Those over 65 had a smaller height (8.2 mm) and greater thickness (4.5 mm). So, 35.3% of elderly specimens scored below the best level for accessibility.

Inter-observer Reliability. Measurement reliability was excellent. Intraclass correlation was high for vertical height (ICC = 0.94), width (ICC = 0.92), and thickness (ICC = 0.93). The standard error ranged from 0.08 to 0.12 mm.
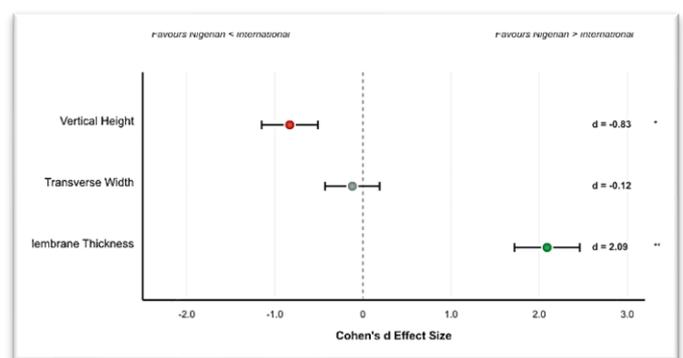

Figure 1 – Comparison of Nigerian Cricothyroid Membrane Dimensions with International Standards

A forest plot showing effect sizes and 95% confidence intervals comparing Nigerian measurements to international standards for vertical height, transverse width, and membrane thickness. Nigerian vertical height shows a significant reduction (Cohen's d = -0.83), while membrane thickness shows a substantial increase (Cohen's d = 2.09) compared to international norms. Error bars indicate 95% confidence intervals.

Note: Effect sizes calculated as Cohen's d with 95% confidence intervals. Negative values indicate Nigerian measurements that are smaller than international standards; positive values indicate measurements that are larger than international standards. The dashed vertical line represents no difference (d = 0).

CONCLUSIONS

Nigerians have a cricothyroid membrane that is shorter and thicker than in other countries. These significant differences mean foreign airway protocols do not fit Nigeria. Emergency doctors should use local facts, not just global rules.

Theoretical Implications. Our results show that human anatomy differs across groups, not just by chance. Thick membranes may arise from genes, growth factors, or local factors [18]. The Igbo group is the most distinct, indicating that Africa is highly diverse [19].

Nigerians challenge the traditional anatomical model by exhibiting a short, thick membrane; this may be due to local adaptation or genetic drift, as seen in other African head shapes [20].

Practical Implications. Emergency medicine in Nigeria should adopt new rules and tools to address these differences. Smaller membranes are easier to find but need small tools. Thicker membranes are easier to feel but require more force and new skills.

Medical schools in Nigeria should teach local anatomy, not just Western facts. Training should accommodate both men and women, given the significant differences between them.

Health leaders should buy equipment and plan care based on local anatomy. Different regions and groups may need other rules.

This study shows that every country should check its own anatomy. If Western data do not match, local rules are better. We need personalised medicine in emergencies. New airway rules should use patient facts to pick the best care.

Limitations. Cadaver studies have limits because bodies change after death [17]. Also, most samples were from cities. Rural Nigerians may be different. We studied only three regions, but Nigeria has over 250 ethnic groups. Our results may not fit everyone. Different people may measure points differently, which can change the exact results. For global comparison, we used published studies rather than our own measurements.

Future Research Directions. Future studies should link these measurements to clinical outcomes in patients. Large trials comparing local and standard protocols can demonstrate how anatomical variation affects care.

Studying other African groups can reveal what is distinctive to Nigeria and what is common across Africa. Long-term studies can determine whether changes are due to age or to differences across generations.

Researchers should test new cricothyrotomy tools and methods to determine whether they align with these findings. Cost studies can help health leaders choose the most effective and affordable protocols.

Genetic studies can determine whether these differences result from adaptation, genetic drift, or the environment; this will help us better understand human anatomy.

This study shows that Western anatomical data do not always apply to emergency airway care worldwide. Nigerian patients need protocols tailored to their unique anatomy; this changes how we view diversity in emergency medicine.

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