

**Geometric characterization of thyroid cartilage in adult humans for biomechanical modeling**Yadav Y\*, Tuli A<sup>2</sup>, Kakar S<sup>2</sup>, Choudhry R<sup>2</sup>, Murari A.<sup>3</sup>

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**Abstract**

The study was conducted on 50 thyroid cartilages (36 males & 14 females) obtained from unclaimed bodies in the Department of Forensic medicine, LHMC. The linear and angular measurements were taken with help of vernier calipers and goniometer and observations were tabulated and statistically evaluated. The distance between laryngeal prominence and posterior edges was found greater than the other researchers. Inter cornual distance between the two superior cornua was greater in the present study and more so in female than male. Superior to inferior cornua length was greater in male than female and more on left side than the right. The angle between thyroid laminae was greater in female than male. In male it was less than 90° and least found in the present study. The posterior edges are found to be curved and directed medially from above downwards and are not in vertical plane. The anterior gap between the thyroid cartilage and the cricoid cartilage was 9.91±0.35 mm in male and 8.70±0.31 in female. This distance is very important for biomechanical modeling vocal cord length changes and fundamental frequency control. The distance between anterior thyroid notch to inferior border was greater in male than in female. This distance is a guide to making incision for supraglottic laryngectomy and type II thyroplasty.

**Keywords:** larynx, laryngeal framework, thyroid cartilage, morphometric measurements**Introduction**

The precise understanding of anatomical structures is the basic precondition of any surgical intervention. There are several reasons why the dimensions of the larynx should be known, such as for intubation, endoscopic procedures, stenting, cricothyroidotomy and transplantation. In the region of head and neck, the increasing application of sophisticated electrophysiological and surgical methods in diagnosis and treatment of laryngeal disorders i.e. subglottic stenosis and post intubation stenosis of lower respiratory tract, require a profound knowledge of size and proportion of human larynx and its cartilaginous components. The thyroid cartilage is the largest of laryngeal cartilages. It consists of two flattened quadrilateral alae fused in the midline anteriorly to form an angle of 90° in male and 120° in females. In male, the fused anterior borders form a projection that can be seen subcutaneously in the front of the neck as the laryngeal eminence or Adam's apple.<sup>1,2</sup> The increasing application of sophisticated electrophysiological, radiological and surgical methods to the diagnosis and treatment of laryngeal disorders requires a profound knowledge of the size and proportion of human larynx and its cartilaginous components. Recent interest in the condition of subglottic stenosis and post- intubational stenosis of the lower respiratory tract<sup>3</sup> prompted us to ascertain the measurements of laryngeal cartilages. Although some information was available on the

dimensions of the human laryngeal cartilages in the Western population, e.g.; (Eckel et al)<sup>4</sup> North Americans (Maue and Dickson)<sup>5</sup> and Nigerians (Ajmani)<sup>6</sup>, information in Indian population was scanty (Ajmani<sup>7</sup> and Harjeet & Jit<sup>8</sup>). Hence the present work was done on the morphometry of thyroid cartilages in autopsy specimens.

### Material and Methods

The study was conducted in Department of Anatomy, Lady Hardinge Medical College (LHMC) & associated S.K. Hospital on 50 thyroid cartilages (36 males & 14 females). The specimens were obtained during autopsy of unclaimed bodies from Department of Forensic Medicine, LHMC & associated S.K. Hospital. The larynges were removed together with trachea from level of hyoid bone to third tracheal ring only when autopsy records, premorbid medical records and gross examination revealed no anatomical abnormalities. During autopsy, a midline incision was given from chin to pubic symphysis to examine various viscera. After identifying the thyroid prominence, larynx was removed en bloc from base of tongue to the second or third tracheal ring. After removal, it was washed under running water and soft tissues removed. After careful removal of all muscles and ligamentous attachments the cartilages were measured in all their dimensions with help of scale, Vernier caliper and a goniometer. Geometric measurements on the laryngeal framework necessary for modeling purposes were defined as follows:

#### Thyroid Cartilage (Fig. 1-4)

- (i) Laryngeal prominence to posterior edges: distance from laryngeal prominence to the posterior margins of laminae (E-F').
- (ii) Inferior cornu to inferior cornu: distance between tips of right and left inferior cornua (B-B').
- (iii) Superior cornu to superior cornu: distance between tips of right and left superior cornua (A-A').
- (iv) Inferior cornu to superior cornu, right: distance between tips of right superior and inferior cornua (A'-B').
- (v) Inferior cornu to superior cornu, left: distance between tips of left superior and inferior cornua (A-B).
- (vi) Left to right width of posterior edges (midvertical): inner distance between posterior edges at laryngeal prominence level (C-C').
- (vii) Left to right width at vocal fold level (inside): inner distance between posterior edges at the vocal fold level (D-D').
- (viii) Anterior to posterior length, bottom: inside antero-posterior length of inferior border of the thyroid lamina (G-G').
- (ix) Anterior to posterior length at vocal fold level: antero-posterior inner length of the thyroid lamina at vocal fold level (O-D).
- (x) Anterior thyroid notch to inferior border: distance between the thyroid notch to inferior border in median plane (E-E').
- (xi) Angle between thyroid laminae: angle between two thyroid laminae at the thyroid prominence measured from outside ( $\alpha$ ).
- (xii) Angle between anterior seam and posterior edge: angle between the anterior seam i.e. where two anterior borders of laminae meet and the posterior edge measured from the inferior aspect ( $\theta$ ).
- (xiii) Superior thyroid seam thickness: thickness of thyroid seam at the level of thyroid prominence (E-F).
- (xiv) Middle thyroid seam thickness: thickness of the thyroid seam at the level of vocal fold.
- (xv) Inferior thyroid seam thickness: thickness of the thyroid seam at the level of inferior border (E'-G).
- (xvi) Anterior gap between thyroid and cricoid cartilages: distance between the lower border of the thyroid cartilage and the upper border of the cricoid arch in the median plane (E'-K').

### Observations and Results

The data obtained from measurement of 50 cricoid cartilages (36 males & 14 females) were analyzed by Student's T-test. P-value obtained by this test said to be significant if it is less than 0.05, highly significant if p value <0.01 and very highly

significant if  $p$  value  $<0.001$ . The average age of males was  $42.6\pm 8.7$  years, maximum being 58 years and minimum 28 years. The average age of females was  $30.2\pm 6.6$  years; maximum was 39 years and minimum 22 years  $\{p = 0.001\}$ . The average height of males was  $163.1\pm 3.6$  cm (max. 171 cm & min. 157 cm; in females that was  $156.0\pm 3.4$  cm (max. 161 cm & min. 151 cm)  $\{p = 0.000\}$ . Observation of the thyroid cartilage revealed that some measures were more variable than others. Table I shows means of various measurements of thyroid cartilages in two sexes.

### Discussion

In Homo sapiens, vocal performance has reached its highest degree of versatility, with a vocal fold capable of adjustment in length, tension and shape. In the course of organic evolution, man appears to have chosen the ability to speak and sing over the security that an intralaryngeal epiglottis would have given him.<sup>9</sup> In the region of head and neck, the increasing application of sophisticated electrophysiological and surgical methods in diagnosis and treatment of laryngeal disorders i.e. subglottic stenosis and post intubation stenosis of lower respiratory tract, require a profound knowledge of size and proportion of human larynx and its cartilaginous components.<sup>4</sup> The thyroid cartilage is the largest of laryngeal cartilages. It consists of two flattened quadrilateral alae fused in the midline anteriorly. In male, the fused anterior borders form a projection that can be seen subcutaneously in the front of the neck as the laryngeal eminence or Adam's apple. A small narrow strip of cartilage, called, the intrathyroid cartilage, separate the two alae anteriorly in childhood. The V-shaped thyroid notch is situated just above the laryngeal eminence. The superior and inferior cornua project from the posterior border of each ala. The superior cornu passes upward and backward, ending in rounded knob to which the lateral thyrohyoid ligament attaches, whereas the shorter inferior cornu articulates on its inner aspect with cricoid cartilage at the cricothyroid joint. The most interesting observation of the present study is that there is wide individual variation in most parameters of the thyroid cartilages. The distance between laryngeal prominence and posterior edges was greater than the other researchers. The angle between thyroid laminae was  $75.55\pm 4.31$  in male and  $100.38\pm 9.05$  in female ( $p = 0.000$ ). In male it was less than  $90^\circ$ , the least found our study. The difference in findings of the present study and that of Ajmani et al<sup>7</sup> may be due to measurement taken at different sites on the anterior seam of thyroid cartilage. Asymmetry has been reported by Hirano et al<sup>10</sup> in thyroid cartilage i.e. it is tilted to right side in right handed individuals. However in the present study the maximum difference between right side and left side measurements of superior to inferior cornua distance was found to be 0.87 mm and 0.69 mm in male and female respectively, left being more than right. Inter cornual distance between the two superior cornua was greater in the present study and more so in female than male by 2.08 mm. ( $p = 0.000$ ). The ratios of The anterior-posterior length (A-P length) at the inferior level, at vocal fold level and at thyroid prominence level with respect to inferior were 1: 1.20:1.39 in male and 1: 1.18: 1.35 in female. The thyroid lamina is wider in Indians when compared with Japanese<sup>11</sup>. The ratio of left – right width (L-R width) at vocal fold level and at thyroid prominence level in male was 1: 1.18 and in female was 1:1.20. This confirms that the posterior edges are curved and directed medially from above downwards and are not in vertical plane. The anterior gap between the thyroid cartilage and the cricoid cartilage is very important for biomechanical modeling vocal cord length changes and fundamental frequency control. The distance between anterior thyroid notch to inferior border or the midline length is a guide to making incision for supraglottic laryngectomy and type II thyroplasty. Significant correlation was found between angle of thyroid laminae and between inter superior cornual distance in male ( $r=0.560$ ). The morphometric data obtained are useful for construction and refinement of quantitative biomechanical models of vocal fold vibration and posturing, e.g. continuum mechanical models<sup>11</sup> and finite-element models of vocal folds.<sup>12</sup>

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**Table- I: Showing various parameters of Thyroid cartilage in male and female**

S. No.	PARAMETER	MALE			FEMALE			p-VALUE
		MEAN	SDEV	RANGE	MEAN	SDEV	RANGE	
1	Laryngeal prominence to posterior edges	38.56	2.67	34.18 - 43.83	31.81	2.23	28.91 - 35.82	0.000
2	Inferior cornu to inferior cornu	33.64	1.98	31.05 - 38.86	27.96	1.82	25.42 - 31.66	0.000
3	Superior cornu to superior cornu	38.43	2.20	34.29 - 43.25	40.51	1.21	38.26 - 42.24	0.003
4	Superior cornu to inferior cornu, right	44.24	4.07	35.61 - 50.81	36.35	0.99	35.36 - 39.221	0.000
5	Superior cornu to inferior cornu, left	45.11	3.61	37.51 - 50.96	37.04	1.14	35.78 - 38.76	0.000
6	Left to right width of posterior edges (midvertical)	40.16	2.69	36.28 - 44.68	31.61	1.23	33.76 - 37.47	0.000
7	Left to right width at vocal fold level (inside)	33.89	2.21	30.97 - 37.82	28.95	0.59	28.77 - 30.16	0.000
8	Anterior to posterior length, bottom	27.80	2.94	21.92 - 33.72	23.50	0.84	22.81 - 25.46	0.000
9	Anterior to posterior length at vocal fold level	33.50	1.35	30.85 - 37.36	27.75	0.66	26.96 - 28.96	0.000
10	Anterior thyroid notch to inferior border	16.57	1.37	14.86 - 19.94	14.10	0.72	13.28 - 15.72	0.000
11	Angle between thyroid laminae	75.55	4.31	70 - 85	100.38	9.05	91-116	0.000
12	Angle b/w anterior seam and posterior cornu	33.05	3.05	29 - 38	28.63	0.74	28 - 30	0.000
13	Superior thyroid seam thickness	3.54	0.72	1.98 - 4.85	2.93	0.14	2.78 - 3.13	0.001
14	Middle thyroid seam thickness	2.99	0.55	1.68 - 4.12	2.55	0.18	2.34 - 2.83	0.002
15	Inferior thyroid seam thickness	2.43	0.74	1.36 - 3.86	2.23	0.28	1.88 - 2.59	0.277
16	Anterior gap between thyroid cricoid cartilage	9.91	0.37	9.15 - 11.02	8.70	0.31	8.12 - 9.02	0.000

**Table-II: Comparison between Various Studies**

-	Present		Ajmani (I) <sup>7</sup>		Tayama <sup>11</sup>		Eckel <sup>4</sup>		Zrunek <sup>14</sup>		Ajmani(N) <sup>6</sup>		Maue <sup>5</sup>	
	male	female	male	female	male		male	female	male	female	male	female	male	female
THYROID														
Laryngeal prominence to posterior edges	38.56	31.81	29.60	26.10	37.27	28.91			41.90	30.20	37.92	35.25	36.99	29.11
Inferior cornu to inferior cornu	33.64	27.96			34.80	25.44	35.90	29.90	37.50	28.80	38.25	31.20	31.83	34.92
Superior cornu to superior cornu	38.43	40.51			35.50	40.77	38.20	36.90					36.25	32.54
Superior cornu to inferior cornu, right	44.24	36.35			43.07	35.48	43.90	36.00	49.00	38.40	44.82	37.25	43.09	37.20
Superior cornu to inferior cornu, left	45.11	37.04			46.38	36.10	45.10	36.50					45.59	38.98
Left to right width of posterior edges (midvertical)	40.16	34.61			41.65	34.05			46.50	38.80			39.43	32.15
Left to right width at vocal fold level (inside)	33.89	28.95			34.05	28.91								
Anterior to posterior length, bottom	27.80	23.50			29.70	22.90								
Anterior to posterior length at vocal fold level	33.50	27.75			34.05	27.09								
Anterior thyroid notch to inferior border	16.57	14.10			19.24	13.59	18.50	15.80					37.15	26.04
Angle between thyroid laminae	75.55	100.38	78.70	106.10	77.17	89.80					89.92	106.38		
Angle b/w anterior seam and posterior cornu	33.05	28.63			35.22	28.60								
Superior thyroid seam thickness	3.54	2.93			4.13	2.80								
Middle thyroid seam thickness	2.99	2.55												
Inferior thyroid seam thickness	2.43	2.23			3.68	2.12								
Anterior gap between thyroid cricoid cartilage	9.91	8.70			10.16	8.06								



Figure-1: Posterior View



Figure 2: superior View



Figure 3: Lateral View

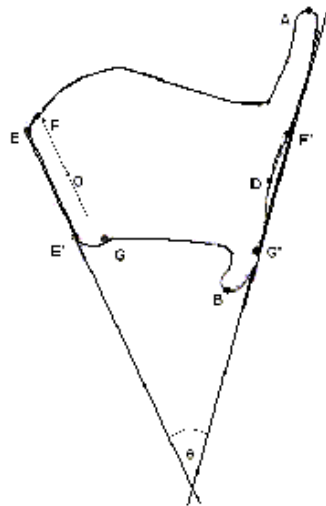
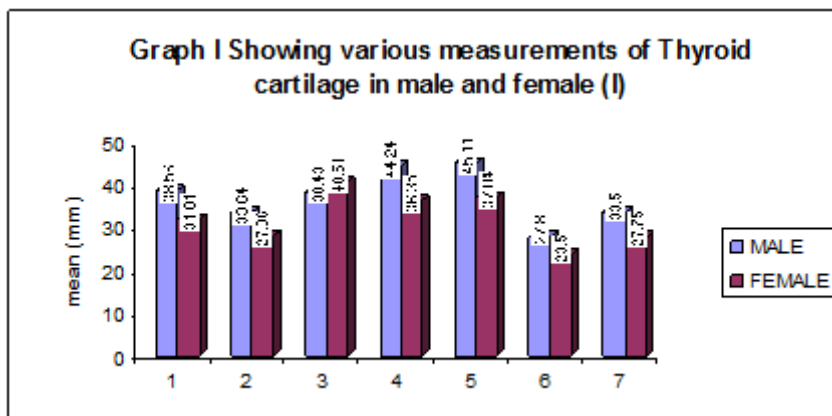
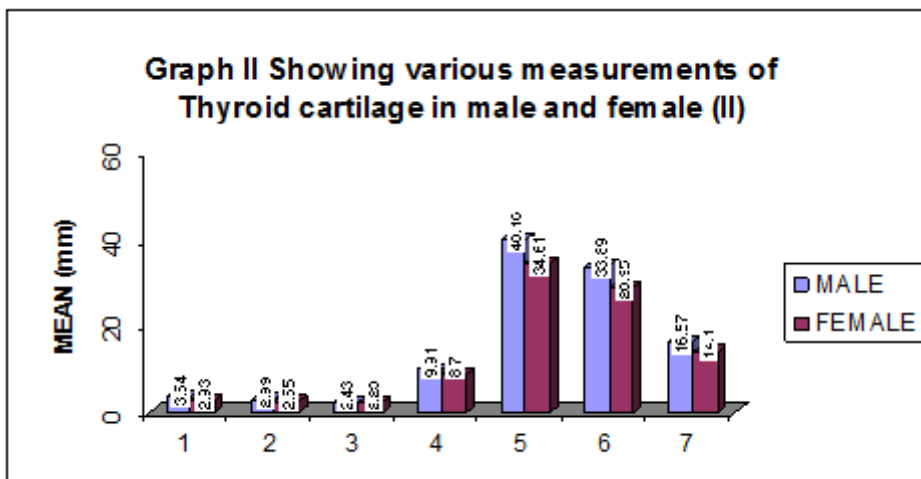


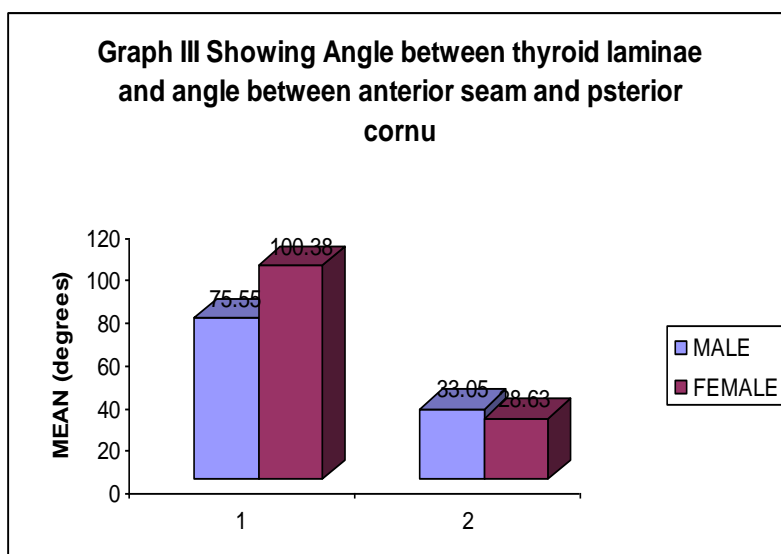
Figure 4: lateral View schematic diagram



1. Laryngeal prominence to posterior edges
2. Inferior cornu to inferior cornu
3. Superior cornu to superior cornu
4. Inferior cornu to superior cornu, right
5. Inferior cornu to superior cornu, left
6. Anterior to posterior length, bottom
7. Anterior to posterior length at vocal fold level



1. Superior thyroid seam thickness
2. Middle thyroid seam thickness
3. Inferior thyroid seam thickness
4. Anterior gap between thyroid cricoid cartilage
5. Left to right width of posterior edges (midvertical)
6. Left to right width at vocal fold level (inside)
7. Anterior thyroid notch to inferior border



1. Angle between thyroid laminae
2. Angle b/w anterior seam and posterior cornu