

The asymmetry index of the cricoid cartilage and the external angle of the thyroid cartilage. A sex-related study

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SUMMARY

The aim of the study was to assess whether the transverse diameter is directly proportional, and the anterior-posterior diameter inversely proportional, to the angle of the thyroid cartilage, thus determining the degree of asymmetry in relation to age and sex, by comparing specimens of larynxes. Analyses were performed on specimens of larynxes from cadavers: 50 male and 50 female. The age range varied from 40 to 98 years, with an average of 58.68. Macroscopic analysis for the presence of lesions was performed with the aid of a magnifying glass. A goniometer (*Carcí®*) was used to obtain the angle of aperture of the two laminae of the thyroid cartilage. The internal dimensions of the cricoid cartilage were obtained using a digital pachymeter (*Starrett® Tolls*). The asymmetry index of the antero-posterior and transverse measurements of the cricoid cartilage was obtained for both sex groups.

The correlation between the angle of the thyroid cartilage and degree of asymmetry of the cricoid cartilage was insignificant in both males ($r=0.027$; $p=0.426$) and females ($r=0.010$; $p=0.472$). These findings suggest that there is no relationship between the angle of the thyroid cartilage and the degree of

asymmetry of the cricoid cartilage. However, a significant difference was observed between the sexes in the transverse and antero-posterior diameters of the cricoid cartilage. Contrary to expectations, the findings failed to show the suggested relationship between the asymmetry index of the internal diameters of the cricoid cartilage and the external angle of the thyroid cartilage.

Key words: Larynx – Anatomy – Morphometry – Cricoid cartilage – Thyroid cartilage – Asymmetry

INTRODUCTION

It is important to determine the size and proportion of the larynx, principally the cartilaginous structure, due to the use of procedures such as intubation, endoscopy and surgical manipulation. Several studies addressing this issue have focused on the dimensions of the cricoid cartilage and trachea and the measurements of the laryngeal skeleton (Ajmani, 1990; Sprinzl et al., 1999; Randestad et al., 2000). However, the literature lacks comparisons between the antero-posterior and transverse diameters of the cricoid cartilage in relation to the external angle of the thyroid cartilage. The

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aim of reporting these measurements is to assess whether there is a direct proportional relationship between the transverse diameter and the external angle of the thyroid cartilage, in which case the antero-posterior diameter would be inversely proportional to this angle. Larynxes (specimens from cadavers) were compared in order to determine the degree of asymmetry. With this, we aim to be able to better assess the larynx for the purposes of endoscopy and surgery.

MATERIAL AND METHODS

One hundred larynxes (free of lesions) from cadavers, fixed in a solution of 10% formaldehyde (< 4 weeks), were explored at autopsy in the Instituto Médico Legal de Porto Alegre (Porto Alegre Medical Examiner's/Coroner's Institute), during the period from August 1999 to October 2000. All specimens were fixed in the same manner. Fifty specimens of larynxes were from males and fifty from females. The age range varied from 40 to 98 years, with an average age of 58.68 years (Table 1).

Table 1. Age range.

AGE RANGE	FREQUENCY	%
40 to 49 years	26	26.0
40 to 59 years	30	30.0
40 to 69 years	20	20.0
70 or over	24	24.0
TOTAL	100	100.0

The pieces were removed from the autopsied corpses, performing sectioning at the level of the supra-hyoideal, as the cranial limit, and at the 7th tracheal ring as the caudal limit. The pieces included the supra and infrathyroid muscles, and the hypopharynx, the cervical oesophagus and the recurring (inferior) laryngeal nerves. The thyroid cartilage was dissected, so that the perichondrium together with the cricoid cartilage and tracheal rings were totally exposed.

The transverse (Fig. 1) and antero-posterior diameters (Fig. 2) of the cricoid cartilage, including the mucous membrane were measured with the aid of a digital pachymeter (Starrett® Tolls, number 727-6/150; series 0002317). Measurements were taken on the horizontal plane, at the caudal limit of the cricoid cartilage.

A goniometer (Carcí®) was used to measure the external angle (Fig. 3) aperture of the lam-

inas of the thyroid cartilage. In order to measure the exact angle of the external aperture of the cartilage, a needle (size, 25x7) was introduced parallel to the vocal folds at the level of the antero commissure, piercing through the cartilage.

The degree of asymmetry of the diameter of the cricoid cartilage was represented by the asymmetry index (CDAI), defined as follows:

$$\text{CDAI} = \frac{\text{APD} - \text{TD}}{(\text{APD} + \text{TD})/2}$$

where APD represents the value found for the antero-posterior diameter, and TD represents the value found for the transverse diameter, both from the cricoid cartilage. The unit of measurement adopted for this procedure was the millimetre (mm). When the value for both the diameters was the same, the CDAI value was equal to zero. Where the antero-posterior diameter of the cricoid cartilage is greater than the transverse diameter from the same cartilage, the value of the CDAI is positive. Where the antero-posterior diameter is smaller than the transverse diameter of the cricoid cartilage (Fig. 4), the CDAI has a negative value. Values are expressed in millimetres.

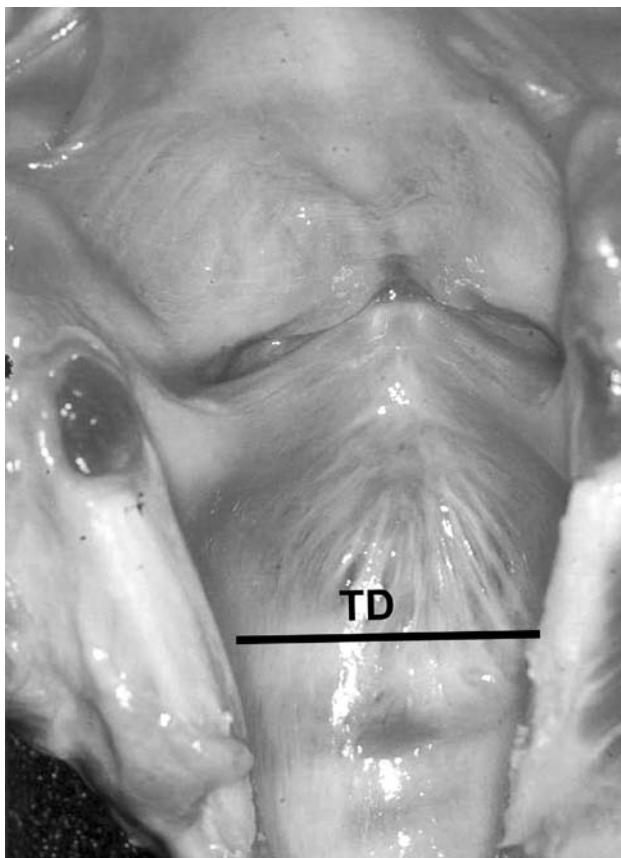
The research was approved by the Comitê de Ética em Pesquisa do Instituto de Cardiologia – Fundação Universitária de Cardiologia (IC-FUC), (Research Ethics Committee of the Institute of Cardiology – University Foundation of Cardiology). Statistical analysis of the measurements of the diameters from the cricoid cartilage and the angle of the thyroid cartilage was performed using Student's t-test, where the level of rejection of the null hypothesis was set at 0.05 or 5% ($\alpha \leq 0.05$) and significant values are indicated by an asterisk (*).

RESULTS

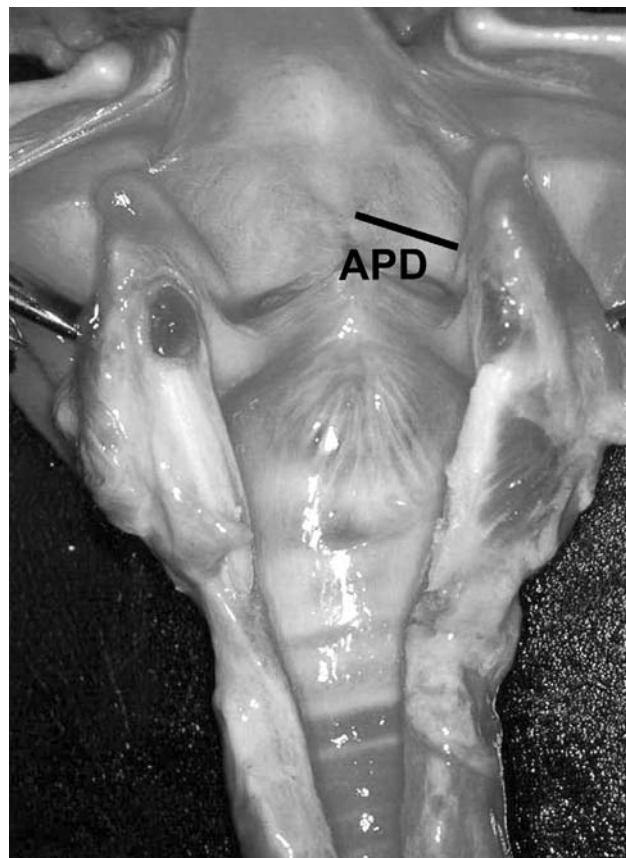
The results obtained using linear regression analysis of the asymmetry index between the diameters of the cricoid cartilage and the external angle of the thyroid cartilage show that there is no relationship between the two compared measurement (Graph 1 and Tables 2, 3 and 4).

The correlation between the external angle of the thyroid cartilage and the cricoid cartilage diameter asymmetry index (CDAI) was not significant in males ($r=-0.027$; $p=0.426$), in females ($r=0.010$; $p=0.472$), or in the total ($r=-0.122$; $p=0.113$).

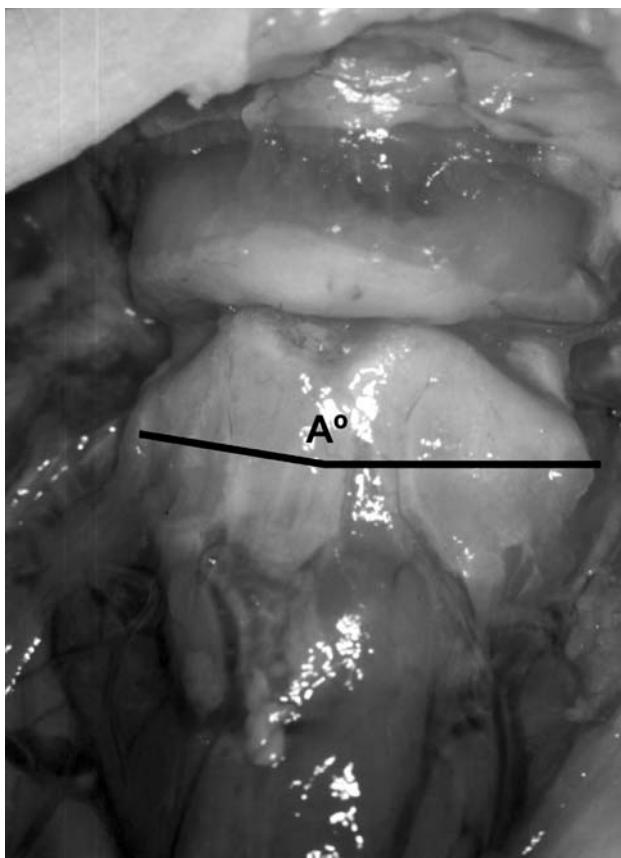
Figures 1-4. Technique employed to obtain the measurements in this study.



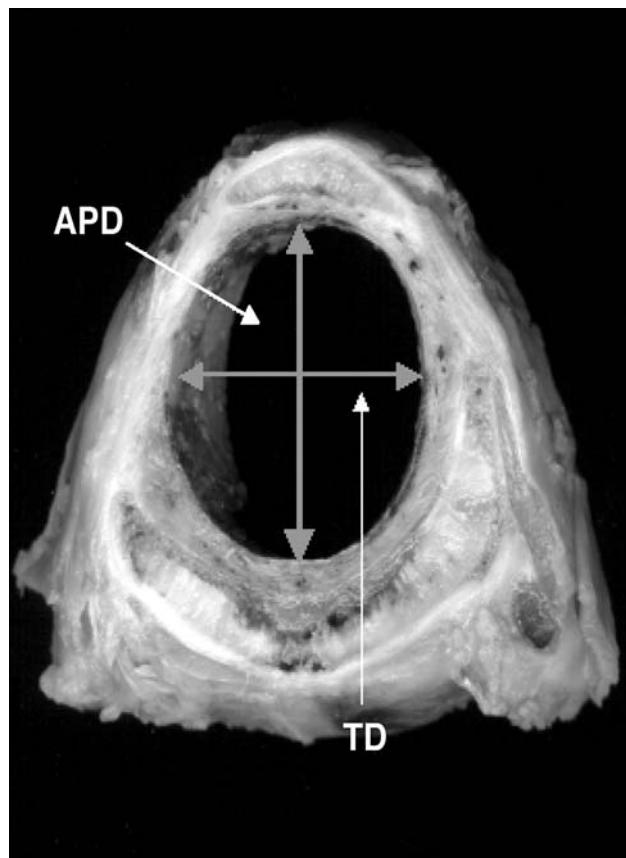
1. TD: Transverse Diameter.



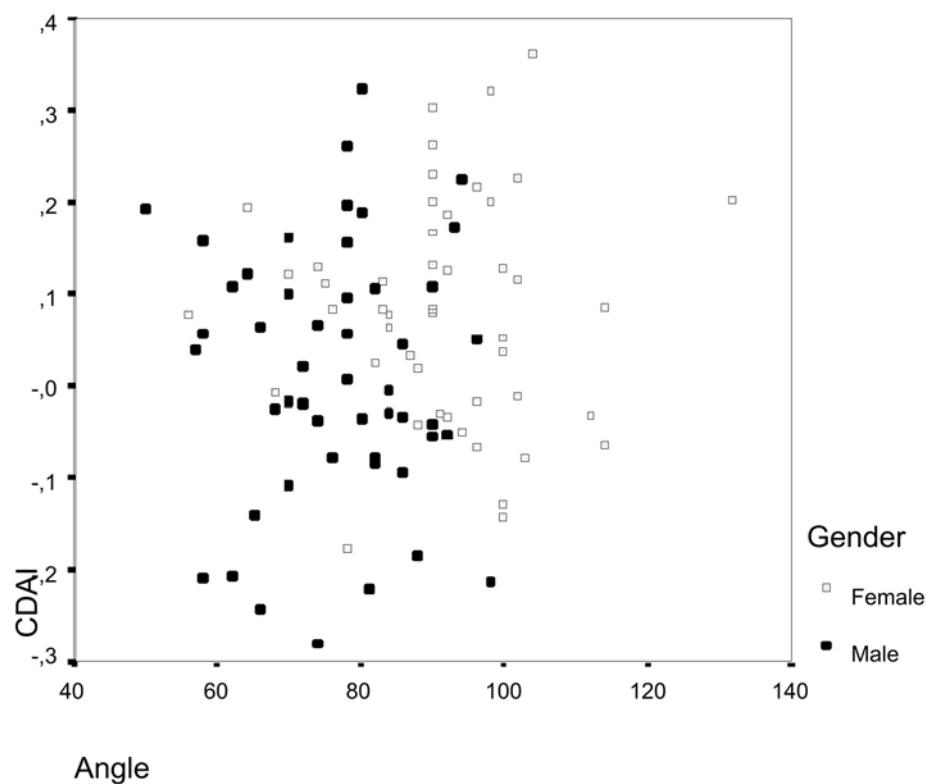
2. APD: Antero-Posterior Diameter.



3. Anterior view of the larynx. A°: Angle of aperture of the thyroid cartilage.



4. Tranversal section of the larynx. APD: Antero-Posterior Diameter; TD: Transverse Diameter.



Graph 1. The distribution of CDAI with respect to the angle of the thyroid cartilage by sex.

Table 2. Descriptive statistics for the quantitative variables of both sexes. Age is expressed in years; AP-D: Antero-Posterior Diameter; T-D: Transverse Diameter; CDAI: Cricoid cartilage Diameter Asymmetry Index.

	N	MINIMUM	MAXIMUM	MEAN	STANDARD DEVIATION
Age	100	40.00	98.00	58.68	13.31
Angle (°)	100	50.00	132.00	83.88	14.34
D-AP(mm)	100	11.58	22.87	16.89	2.69
D-T (mm)	100	9.89	22.94	16.20	2.88
CDAI	100	-0.28	0.36	0.04	0.13

Table 3. Descriptive statistics for the quantitative variables of the males. Age is expressed in years; APD: Antero-Posterior Diameter; TD: Transverse Diameter; CDAI: Cricoid cartilage Diameter Asymmetry Index.

	N	MINIMUM	MAXIMUM	MEAN	STANDARD DEVIATION
Age	50	40.00	92.00	54.86	12.15
Angle (°)	50	50.00	98.00	76.68	11.35
APD(mm)	50	14.52	22.87	18.63	2.26
TD (mm)	50	13.62	22.94	18.39	1.86
CDAI	50	-0.28	0.32	0.01	0.14

Table 4. Descriptive statistics for the quantitative variables of the females. Age is expressed in years; APD: Antero-Posterior Diameter; TD: Transverse Diameter; CDAI: Cricoid cartilage Diameter Asymmetry Index.

	N	MINIMUM	MAXIMUM	MEAN	STANDARD DEVIATION
Age	50	40.00	98.00	62.50	13.44
Angle (°)	50	56.00	132.00	91.08	13.44
APD (mm)	50	11.58	20.79	15.15	1.84
TD (mm)	50	9.89	19.72	14.01	1.87
CDAI	50	-0.18	0.36	0.08	0.12

The t-test was used for comparison of the means obtained in each group. When the t

statistic is significant, the value of p is lower than 0.05 or 0.01 (Table 5).

Table 5. T-test for the comparison of means of the quantitative variables by sex.

	SEX	N	MEAN	STANDARD DEVIATION	t-TEST	P
Angle (°)	Male	50	76.68	11.35	-5.79**	0.000
	Female	50	91.08	13.44		
APD(mm)	Male	50	18.63	2.26	8.46**	0.000
	Female	50	15.15	1.84		
TD (mm)	Male	50	18.39	1.86	11.74**	0.000
	Female	50	14.01	1.87		
CDAI	Male	50	0.01	0.14	-2.61*	0.010
	Female	50	0.08	0.12		

* Statistic t significant at a level of 5%.

* Statistic t significant at a level of 1%.

It may be seen from the values obtained for the asymmetry index that there was no directional tendency in males:

50% of the CDAI values were positive, indicating that the antero-posterior diameter of the cricoid cartilage was larger than the transverse diameter, and 50% of the CDAI values were negative, indicating that the antero-posterior diameter was smaller than the transverse diameter of the cricoid cartilage.

In the females, the antero-posterior diameter of the cricoid cartilage was larger than that of the transverse diameter (IA has a positive value) in 70% of the sample (Tables 6 and 7).

Table 6. ANOVA Test (Analysis of Variance) for comparison of the variables by age groups (Males). Age is expressed in years; APD: Antero-Posterior Diameter; TD: Transverse Diameter; CDAI: Cricoid cartilage Diameter Asymmetry Index.

	AGE	N	MEAN	STANDARD DEVIATION	F	P
Angle (°)	40-49 years	16	77.19	10.85	0.47	0.706
	40-59 years	19	77.26	10.22		
	40-69 years	8	78.38	13.48		
	70 or over	7	72.00	14.19		
	Total	50	76.68	11.35		
APD (mm)	40-49 years	16	18.18	2.63	1.09	0.361
	40-59 years	19	18.50	1.84		
	40-69 years	8	19.91	2.07		
	70 or over	7	18.55	2.52		
	Total	50	18.63	2.26		
TD (mm)	40-49 years	16	18.36	1.57	0.36	0.779
	40-59 years	19	18.63	2.34		
	40-69 years	8	18.45	1.52		
	70 or over	7	17.75	1.52		
	Total	50	18.39	1.86		
CDAI	40-49 years	16	-0.02	0.13	0.91	0.445
	40-59 years	19	0.00	0.17		
	40-69 years	8	0.07	0.10		
	70 or over	7	0.04	0.10		
	Total	50	0.01	0.14		

Table 7. ANOVA Test (Analysis of Variance) for comparison of the variables by age groups (Females). Age is expressed in years; APD: Antero-Posterior Diameter; TD: Transverse Diameter; CDAI: Cricoid Cartilage Diameter Asymmetry Index.

	AGE	N	MEAN	STANDARD DEVIATION	F	P
Angle (°)	40 - 49 years	10	95.60	12.28	1.13	0.345
	40 - 59 years	11	89.64	19.82		
	40 - 69 years	12	85.92	14.21		
	70 or over	17	93.00	6.79		
	Total	50	91.08	13.44		
APD (mm)	40 - 49 years	10	15.87	1.64	1.27	0.294
	40 - 59 years	11	14.35	1.41		
	40 - 69 years	12	15.06	2.15		
	70 or over	17	15.31	1.92		
	Total	50	15.15	1.84		
TD (mm)	40 - 49 years	10	14.65	2.07	1.65	0.190
	40 - 59 years	11	12.99	1.76		
	40 - 69 years	12	14.04	1.84		
	70 or over	17	14.28	1.74		
	Total	50	14.01	1.87		
CDAI	40 - 49 years	10	0.08	0.15	0.20	0.899
	40 - 59 years	11	0.10	0.13		
	40 - 69 years	12	0.07	0.10		
	70 or over	17	0.07	0.12		
	Total	50	0.08	0.12		

DISCUSSION

The morphological aspects of the larynx have been studied in different ethnic groups. In the morphological study of the laryngeal skeleton in adult Nigerians, reported by Ajmani (1990), 40 specimens of larynxes were evaluated, of which 12 were female and 28 male, with ages that varied from 17 to 50 years. Significant differences were noted in the size of the larynxes between the sexes – larger in men and smaller in women, including the antero-posterior and transverse diameters. Furthermore, the differences between the dimensions of the cricoid cartilage of the men in relation to the women were the most signif-

icant. In the same study, the authors noted that the angle of the thyroid cartilage was significantly larger in women than in men, varying from 60° to 106° in the men and from 88° to 132° in the women. Similarly, it can be noted in the present study that the angle of the thyroid cartilage varied from 50° to 132°. In men the variation was from 50° to 98° and in the women it was from 56° to 132°. Contrary to the findings of Ajmani's study (1990), here a trend towards a larger antero-posterior diameter was observed in the females in comparison to the males, although this difference was not significant in this sample. It was also found that the transverse diameter of the cricoid cartilage was larger than that of the antero-posterior in both sexes. In comparison, with regard average measurements of the transverse diameter, Ajmani (1900) noted that in the men it was from 29.84 ± 6.10 mm, and in the women it was from 25.84 ± 3.48 mm. The diameter of the average antero-posterior diameter in the men was from 28.82 ± 4.07 mm, and in the women 24.06 ± 2.53 mm.

Randestad et al. (2000) studied the dimensions of the cricoid cartilage and trachea in 34 men and 27 women. The average size of the transverse diameter found in women with mucous membrane was 13.7 mm with a standard deviation of 1.6 for the women. In men this measurement was 17.9 mm, with a standard deviation of 2.2. With regard the antero-posterior diameter, in women it was 13.9 mm, with a standard deviation of 1.3, while in men it was 17.7 mm with a standard deviation of 2.1. In our study, in the women we noted an average transverse diameter of 14.01 ± 1.87 mm, and in the men an average diameter of 18.39 ± 1.86 mm. For the antero-posterior diameter, the average in women was 15.15 ± 1.84 mm. In men the average was 18.63 ± 2.26 mm. A significant difference was observed in the transverse and antero-posterior diameters of the cricoid cartilage between the sexes ($p < 0.004$). These findings make it possible to positively establish the similarity in the dimensions of the cricoid cartilage between Brazilians and Swedes (Randestad et al., 2000), since these measurements are significantly smaller than those sound in specimens of Indian larynxes. The principal explanation for this discrepancy would probably be due to ethnicity.

Post-mortem alterations to the laryngeal mucous may elicit small changes in the internal measurements of the cricoid cartilage,

although we consider there to be no significant alterations to the measurements when compared to those of living humans. Sprinzl et al. (1999) described a set of pieces that were assessed between 12 and 64 hours post-mortem, and reported no significant alterations attributable to the delay in morphometry, since the pieces were not subjected to fixation. It is known that with fixation in 10% formaldehyde, some reduction may occur in the structural dimensions of the pieces under study, especially the muscles, though in the case of the vocal folds these are firmly attached to the cartilaginous framework. It is known that cartilage very probably maintains the same dimensions as that of living human beings (Randestad et al., 2000). Sprinzl et al. (1999) reported that the ethnic differences found in laryngeal morphometry may not necessarily represent a significant difference when the pieces are subjected to fixing in formalin. However, this was not found in the present study, where the data were comparable to those of European studies and significantly different from values described in studies from Asia, such as those from India, and the fixing of the tissues had little influence, at least in our opinion. Even if such alterations had occurred, due to the fixative process, proportionality would have been seen, since the pieces were fixed using the same method and the measurements were taken in the same post-fixation period.

The internal diameters of endotracheal tubes are expressed in mm. Customarily in our field, endotracheal tubes with internal diameters of 9.5 mm for males and 8.5 mm for females are used. The tubes have walls that vary in thickness between 2 and 3 mm (measured at the insertion point of the deflated bayonet), which means that the space between the wall of the tube and that of the cricoid is minimal. Given this situation, we are opposed to the use of endotracheal tubes that border the laryngeal dimensions, since this increases the risk of causing laryngeal injury, followed by oedema, fibrosis and consequently stenosis, resulting from the close contact of the tube with the laryngeal-tracheal wall mucosa (Table 8). With reference to armoured tubes, the difference between the internal and external diameters is greater than 3.0 mm, where the 8.0 mm curved armoured tracheal tube from Ruschelit® has an external diameter of 11.4 mm. Holinger and Oppenheimer (1989) noted that many children have a very small

infraglottic antero-posterior diameter, an elliptic form that is frequently retained into adulthood.

Table 8. Internal and external diameters of endotracheal tubes used in general anaesthesia in adults in Brazil.

ENDOTRACHEAL TUBES (INTERNAL DIAMETER - mm)	ENDOTRACHEAL TUBES (EXTERNAL DIAMETER - mm)
9.5	13.3
9.0	12.7
8.5	11.3
8.0	10.7
7.5	10.0
7.0	9.3
6.5	8.7
6.0	8.0
5.5	7.3
5.0	6.7

Hirano et al. (1989) studied 50 specimens of larynxes from autopsied corpses of people with ages varying between 0 and 59, of which 10 were new-borns, 20 were aged from 20 to 29, and 20 were aged from 50 to 59 years. No variations were noted in the degree of asymmetry between the ages or the sexes. The authors believe that there must be some compensatory mechanism within the structural asymmetry that acts to maintain the edge of the vocal folds relatively symmetrical. In our study, upon comparing the variable averages assessed by sex using the t-Test, we observed significant differences in all of them (Table 5), while no significant difference was seen between ages (Tables 6 and 7).

Eckel et al. (1994) studied the internal diameter of the cricoid cartilage and the angle of the laminas of the thyroid cartilage in 20 specimens of German origin, with ages varying from 53 to 93 years, in which they noted that the external angle of the thyroid cartilage varied from 58.8° to 100.4° in men, with an average of $70.25^\circ \pm 11.36^\circ$, and from 79.2° to 109.3° in women, with an average of $88.39^\circ \pm 9.44^\circ$. In relation to the transverse diameter of the cricoid cartilage, an average of 13.23 ± 2.53 mm was reported in men, while in women the average was 11.13 ± 2.18 mm. With regard the antero-posterior diameter, averages of 19.65 ± 2.25 mm in men and, 15.79 ± 1.59 mm in women were described. Similar values were observed in descriptions from individuals of Swedish provenance (Randestad et al., 2000) and in our study (Brazilian), while the values were quite different from those of individuals of Indian ethnicity.

It is worth pointing out that Brazil and, more specifically the state of Rio Grande do Sul, where the study was carried out, was colonized by people of European origin, mainly Germans and Italians, which would go some way to explaining the similar values of the larynxes measured.

The results showed that there were no relationship between the angle of the thyroid cartilage and the measurement of the cricoid cartilage; that is, the higher the measurement of the antero-posterior diameter of the cricoid, the smaller the angle of the laminas of the thyroid cartilage should be (Graph 1, Tables 6 and 7). In males, we observed that only 50% had antero-posterior values greater than those of the transverse, and no directional trend was noted. While in the case of the females, in 70% of the samples the transverse diameter was larger than the antero-posterior diameter and there was a directional trend towards higher angles in the thyroid cartilage, although this asymmetry was not statistically significant.

CONCLUSION

Contrary to expectations, our findings failed to reveal the suggested relationship between the asymmetry index of the internal diameters of the cricoid cartilage and the external angle of the thyroid cartilage.

There is a great deal of variation among the laryngeal measurements studied, which may be explained by factors related to ethnicity. We believe that knowledge of such measure-

ments is of fundamental importance for the clinical use and applicability of endotracheal tubes and, principally in order to prevent unnecessary injury to the larynx.

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