A morphometric study of human trachea and principal bronchi in different age groups in both sexes and its clinical implications

R Chunder,[1] S Nandi,[2] R Guha[3] and N Satyanarayana[3]

[1]Department of Anatomy, K. P. C. Medical College and Hospital, 1F, Raja S.C. Mullick Road, Jadavpur, Kolkata-700 032, India, [2]Consultant Surgeon, B.P Poddar Hospital And Medical Research Limited, 71/1, Humayun Kabir Sarani, New Alipore, Kolkata- 700 053, India, [3]Department of Anatomy, College of Medical Sciences, Bharatpur, Chitwan, Nepal

Corresponding author: Dr. Ranjit Guha, Professor, Department of Anatomy, College of Medical Sciences and Teaching Hospital, Bharatpur-23, Chitwan District, Nepal; e-mail: guharanjit@yahoo.co.in

ABSTRACT

An extensive morphometric study of human trachea and principal bronchi was undertaken in the Department of Anatomy, Institute of Post Graduate Medical Education and Research, Kolkata, West Bengal, India, on 87 specimens procured from 51 male and 36 female relatively disease free fresh cadavers from Kolkata Police Morgue. The specimens were grouped into five age groups for both sexes. The length of trachea, principal bronchi, subcarinal angle was measured in each specimen. The external transverse diameter (width), internal transverse diameter and anteroposterior diameter (depth) were recorded at two different levels of trachea (junction of upper third and middle third; middle third and lower third) and middle of principal bronchi. Then the width-depth ratio was calculated. For each component of the measurements, standard error (SE), standard deviation (SD) and test of significance were calculated using independent sample't' test and multiple comparison test. The present investigation revealed a wide variation in different dimensions viz. length, transverse and anteroposterior diameters and width-depth ratio of upper and lower trachea and right and left principal bronchi and the subcarinal angle, in a same age group as well as in different age groups in both sexes. The study of these morphometric variations is of profound clinical importance as it may help the clinicians to understand the etiology of several pulmonary diseases and the surgeons to deal with resection and reconstruction of the tracheobronchial tree. This knowledge is also helpful for smooth conduction of some maneuvers like endotracheal intubation and bronchoscopic procedures.

Keywords: Morphometry, trachea, principal bronchi, cadaveric study.

INTRODUCTION

The trachea is a centrally located membranocartilaginous unpaired hollow organ extending downwards as a continuation of the larynx from a vulnerable superficial position in the neck deep into the well-protected middle of the mediastinum.[1] The trachea extends from the lower border of the cricoid cartilage opposite C6 vertebra up to the upper border of T5 vertebra where it ends by dividing into right and left principal bronchi supplying the right and left lungs respectively.[2]

There is a wide variation in different dimensions viz. length, transverse and anteroposterior diameters and width-depth ratio of the lumen of trachea and principal bronchi and the subcarinal angle in a same age group as well as in different age groups in both sexes.[3] Aside from pure anthropometry, the study of these morphometric variations is of profound clinical importance as it may help the clinicians to understand the etiology of several pulmonary diseases. Infact the pattern of the lower respiratory tract including the variations in length and width-depth ratio of the lumen of the tracheobronchial tree is nowadays considered as the most crucial predisposing factor for a galaxy of respiratory diseases like chronic bronchitis and emphysema.[4]

The knowledge of anatomy particularly with respect to the shape (width-depth ratio) of the conducting and respiratory tube has drawn attention of both, anatomists and clinicians. Pulmonologists are particularly concerned with the relationship between the lumen of the conducting part of the respiratory tract and its significant role in production of allergic states, fibrosis of lungs and pulmonary tuberculosis.[5,6]

With the above factors in limelight, the present study was taken up to measure different dimensions viz. length, transverse and anteroposterior diameters and width-depth ratio of the lumen of trachea and principal bronchi and the subcarinal angle in different age groups of both sexes which might have bearing in the production of respiratory diseases.

Furthermore, an accurate anatomical knowledge of the same is of immense importance in problems of resection and reconstruction of the tracheobronchial tree. Last but not the least, these informations have potential

Table-1: Multiple comparisons of tracheal length and width-depth ratio in both sexes using Tukey's test

Age Group	Age Code	MALE						FEMALE					
		p value Of **Length**	Sig	p value of **WDR-UT**	Sig	p value Of **WDR-LT**	Sig	p value of **Length**	Sig	p value of **WDR-UT**	Sig	p value of **WDR-LT**	Sig
0-15 yrs	2	<0.001	HS	<0.001	HS	<0.001	HS	<0.001	HS	0.744	IS	1.000	IS
(Age	3	<0.001	HS	<0.001	HS	<0.001	HS	<0.001	HS	<0.001	HS	0.001	SG
code1)	4	0.184	IS	<0.001	HS	<0.001	HS	<0.001	HS	0.061	IS	0.961	IS
	5	<0.001	HS	<0.001	HS	<0.001	HS	<0.001	HS	0.001	SG	0.468	IS
16-25 yrs	1	<0.001	HS	<0.001	HS	<0.001	HS	<0.001	HS	0.744	IS	1.000	IS
(Age	3	<0.001	HS	0.801	IS	0.638	IS	0.989	IS	<0.001	HS	<0.001	HS
code 2)	4	<0.001	HS	0.894	IS	<0.001	HS	0.973	IS	0.082	IS	0.796	IS
	5	0.111	IS	<0.001	HS	0.101	IS	0.876	IS	<0.001	HS	0.101	IS
26-40 yrs	1	<0.001	HS	<0.001	HS	<0.001	HS	<0.001	HS	<0.001	HS	0.001	SG
(Age	2	<0.001	HS	0.801	IS	0.638	IS	0.989	IS	<0.001	HS	<0.001	HS
Code3)	4	<0.001	HS	0.998	IS	0.005	SG	1.000	IS	0.006	SG	<0.001	HS
	5	<0.001	HS	<0.001	HS	0.749	IS	0.984	IS	0.985	IS	<0.001	HS
41-55 yrs	1	0.184	IS	<0.001	HS	<0.001	HS	<0.001	HS	0.061	IS	0.961	IS
(Age	2	<0.001	HS	0.894	IS	<0.001	HS	0.973	IS	0.082	IS	0.796	IS
Code4)	3	<0.001	HS	0.998	IS	0.005	SG	1.000	IS	0.006	SG	<0.001	HS
	5	<0.001	HS	<0.001	HS	0.159	IS	0.993	IS	0.063	IS	0.490	IS
> 55 yrs	1	<0.001	HS	<0.001	HS	<0.001	HS	<0.001	HS	0.001	SG	0.468	IS
(Age	2	0.111	IS	<0.001	HS	0.101	IS	0.876	IS	<0.001	HS	0.101	IS
Code5)	3	<0.001	HS	<0.001	HS	0.749	IS	0.984	IS	0.985	IS	<0.001	HS
	4	<0.001	HS	<0.001	HS	0.159	IS	0.993	IS	0.063	IS	0.490	IS

yrs: years, Sig: significance, WDR-UT: Width-Depth Ratio-Upper Trachea, WDR-LT: Width-Depth Ratio-Lower Trachea,HS: Highly Significant, IS: Insignificant, SG: Significant.

applications to studies in pulmonary physiology and anesthesiology as also to conduction of some maneuvers like endotracheal intubation and bronchoscopic procedures (diagnostic, therapeutic and combined) with skill and perfection.[7]

MATERIALS AND METHODS

PROCUREMENT OF MATERIALS

A total number of 87 specimens were procured from 51 male and 36 female relatively disease free fresh cadavers from Kolkata Police Morgue. The specimens were grouped into five age groups (0-15years, 16-25years, 26-40years, 41-55years and >55years) for both sexes. Subsequent study utilizing these specimens was conducted in the Department of Anatomy, Institute of Post Graduate Medical Education and Research (IPGME&R), Kolkata, West Bengal, India.

METHODS

At first a photograph of every specimen was taken. Then the length of the trachea (from the lower border of the cricoid cartilage to the point of the tracheal bifurcation) and the length of the right and left principal bronchi (from the angle of tracheal bifurcation to the point of its dividing into the secondary bronchi) were recorded in centimeter scale in each specimen.

The lumen of the trachea was then cut at two different levels (junction of upper third and middle third; middle third and lower third) with the help of a sharp scalpel to avoid laceration.

Then with the help of a slide-caliper and silk thread, the external transverse diameter (width), internal transverse diameter and anteroposterior diameter (depth) were recorded at both the levels in the metric system upto the fraction of millimeter range. Then the width-depth ratio

Table-2: Multiple comparisons of length and width-depth ratio of right and left principal bronchi in male using Tukey's test

Age Group	Age Code	MALE							
		R P B				LPB			
		p value of Length	Sig	p value of WDR	Sig	p value of Length	Sig	p value of WDR	Sig
0-15 yrs (Age Code1)	2	<0.001	HS	<0.001	HS	<0.001	HS	<0.001	HS
	3	<0.001	HS	0.017	SG	<0.001	HS	0.007	SG
	4	<0.001	HS	0.087	IS	<0.001	HS	0.179	IS
	5	<0.001	HS	0.965	IS	<0.001	HS	0.701	IS
16-25 yrs (Age Code2)	1	<0.001	HS	<0.001	HS	<0.001	HS	<0.001	HS
	3	0.017	SG	0.020	SG	0.009	SG	0.535	IS
	4	0.084	IS	<0.001	HS	<0.001	HS	<0.001	HS
	5	0.003	SG	<0.001	HS	<0.001	HS	<0.001	HS
26-40 yrs (Age Code3)	1	<0.001	HS	0.017	SG	<0.001	HS	0.007	SG
	2	0.017	SG	0.020	SG	0.009	SG	0.535	IS
	4	0.880	IS	0.784	IS	<0.001	HS	<0.001	HS
	5	0.960	IS	0.010	SG	0.436	IS	0.029	SG
41-55 yrs (Age Code4)	1	<0.001	HS	0.087	IS	<0.001	HS	0.179	IS
	2	0.084	IS	<0.001	HS	<0.001	HS	<0.001	HS
	3	0.880	IS	0.784	IS	<0.001	HS	<0.001	HS
	5	0.474	IS	0.078	IS	<0.001	HS	<0.001	HS
>55 yrs (Age Code5)	1	<0.001	HS	0.965	IS	<0.001	HS	0.701	IS
	2	0.003	SG	<0.001	HS	<0.001	HS	<0.001	HS
	3	0.960	IS	0.010	SG	0.436	IS	0.029	SG
	4	0.474	IS	0.078	IS	<0.001	HS	<0.001	HS

yrs: years, RPB: Right Principal Bronchus, LPB: Left Principal Bronchus, Sig: Significance,
WDR: Width-Depth Ratio, HS: Highly Significant, SG: Significant, IS: Insignificant.

was calculated. Similar procedures were repeated at the level of the middle of the right and left principal bronchi in each specimen (Fig. 1).

For each component of the measurements, standard error (SE), standard deviation (SD) and test of significance were calculated using independent sample't' test and multiple comparison test.

Subsequently, the subcarinal angle which is referred to the angle between the two main bronchi, as measured along their inferior borders[8] was measured on the photograph of the specimen. The inferior borders of the right and left principal bronchi were traced with the marker pen and the two lines thus drawn were joined to get the subcarinal angle with the help of a diagonal scale (Fig. 2).

OBSERVATIONS

The mean tracheal length found in this study were 9.07cm, 10.98 cm, 10.76 cm, 10.78 cm, and 10.69cm in males and 6.45 cm, 9.86 cm, 9.93 cm, 9.95 cm and 9.53 cm in females in 0-15 years, 16-25 years, 26-40 years, 41-55 years and >55 years age groups respectively.

The upper external transverse diameters (width) of the trachea were 1.95 cm, 2 cm, 2.1 cm, 2 cm, 2 cm in the males and 1.45 cm, 1.8 cm, 1.7 cm, 1.5 cm, and 1.6cm in females in 0-15 years, 16-25 years, 26-40 years, 41-55 years and >55 years age groups respectively.

The upper anteroposterior diameters (depth) were 1.35 cm, 1.6 cm, 1.7 cm, 1.6 cm and 1.9 cm in the males and 1.15cm, 1.3 cm, 0.9cm, 1 cm and 0.9cm in females in the 0-15 years, 16-25 years, 26-40 years, 41-55 years and >55 years age groups respectively.

The lower external transverse diameters (width) of the trachea were 1.85 cm, 2 cm, 2.1 cm, 2cm and 2.1 cm in males and 1.35 cm, 1.6cm, 1.6cm, 1.7cm and 1.6cm in females in the 0-15 years, 16-25 years, 26-40 years, 41-55 years and >55 years age groups respectively.

Table-3: Multiple comparisons of length and width-depth ratio of right and left principal bronchi in female using Tukey's test

Age Group	Age Code	FEMALE							
		RPB				LPB			
		p value of Length	Sig	p value of WDR	Sig	p value of Length	Sig	p value of WDR	Sig
0-15 yrs (Age Code1)	2	<0.001	HS	0.884	IS	<0.001	HS	0.276	IS
	3	0.438	IS	1.000	IS	0.004	SG	0.496	IS
	4	0.286	IS	0.933	IS	0.013	SG	0.027	SG
	5	0.175	IS	0.694	IS	0.016	SG	0.117	IS
16-25 yrs (Age Code2)	1	<0.001	HS	0.884	IS	<0.001	HS	0.276	IS
	3	<0.001	HS	0.520	IS	<0.001	HS	0.959	IS
	4	<0.001	HS	0.049	SG	<0.001	HS	<0.001	HS
	5	<0.001	HS	0.015	SG	<0.001	HS	<0.001	HS
26-40 yrs (Age Code3)	1	0.438	IS	1.000	IS	0.004	SG	0.496	IS
	2	<0.001	HS	0.520	IS	<0.001	HS	0.959	IS
	4	0.990	IS	0.705	IS	0.903	IS	<0.001	HS
	5	0.853	IS	0.303	IS	0.973	IS	<0.001	HS
41-55 yrs (Age Code4)	1	0.286	IS	0.933	IS	0.013	SG	0.027	SG
	2	<0.001	HS	0.049	SG	<0.001	HS	<0.001	HS
	3	0.990	IS	0.705	IS	0.903	IS	<0.001	HS
	5	0.972	IS	0.905	IS	1.000	IS	0.933	IS
>55 yrs (Age Code5)	1	0.175	IS	0.694	IS	0.016	SG	0.117	IS
	2	<0.001	HS	0.015	SG	<0.001	HS	<0.001	HS
	3	0.853	IS	0.303	IS	0.973	IS	<0.001	HS
	4	0.972	IS	0.905	IS	1.000	IS	0.933	IS

yrs: years, RPB: Right Principal Bronchus, LPB: Left Principal Bronchus, Sig: Significance,
WDR: Width-Depth Ratio, HS: Highly Significant, SG: Significant, IS: Insignificant.

The lower anteroposterior diameters (depth) were 1.05cm, 1.6cm, 1.6cm, 1.5cm and 1.5cm in males and 1.05cm, 1.2 cm, 1.5cm, 1.4cm and 1.5cm in the females in the 0-15 years, 16-25 years, 26-40 years, 41-55 years and >55 years age groups respectively.

The upper internal transverse diameter of the trachea in this study were 1.1cm, 1.1cm, 1.2cm, 1.4cm, 1.4cm in males and 1.3cm, 1.2cm, 1.3cm, 1.1cm and 1.1cm in females in the 0-15 years, 16-25 years, 26-40 years, 41-55 years and >55 years age groups respectively.

The internal transverse diameters of the lower trachea were 0.82cm, 1.1cm, 1.3cm, 1.4cm and 1.4cm in male and 1.2cm, 1.1cm, 1cm, 1cm and 1cm in females in the 0-15 years, 16-25 years, 26-40 years, 41-55 years and >55 years age groups respectively.

The width- depth ratio was measured at two level viz junction of upper third and middle third and the junction of middle third and lower third. The mean width-depth ratio at the upper trachea were 1.45, 1.25, 1.27, 1.27 and 1.11 in males and 1.27, 1.22, 1.86, 1.60 and 1.82 in females in 0-15 years, 16-25 years, 26-40 years, 41-55 years and >55 years age groups respectively.

The width-depth ratio at the lower trachea were 1.76, 1.40, 1.28, 1.38 and 1.33 in males and 1.29, 1.18, 1.47, 1.23 and 1.12 in females in 0-15 years, 16-25 years, 26-40 years, 41-55 years and >55 years age groups respectively.

Different statistical constants including test of significance using independent samples test were computed with regard to the length and width-depth ratio of lumen of upper and lower trachea in different age groups in both sexes. The p value was highly significant for the width-depth ratio of upper trachea of the age groups 26-40 years, 41-55 years and >55 years and

Table-4: Multiple comparisons of subcarinal angle in both sexes using Tukey's test

Age Group	Age Code	MALE		FEMALE	
		p value of SCA	Significance	p value of SCA	Significance
0-15 years (Age Code1)	2	0.848	IS	0.313	IS
	3	0.093	IS	0.690	IS
	4	0.017	SG	0.839	IS
	5	0.848	IS	0.035	SG
16-25 years (Age Code2)	1	0.848	IS	0.313	IS
	3	0.253	IS	0.820	IS
	4	0.032	SG	0.522	IS
	5	1.000	IS	0.380	IS
26-40 years (Age Code3)	1	0.093	IS	0.690	IS
	2	0.253	IS	0.820	IS
	4	0.927	IS	0.989	IS
	5	0.253	IS	0.065	IS
41-55 years (Age Code4)	1	0.017	SG	0.839	IS
	2	0.032	SG	0.522	IS
	3	0.927	IS	0.989	IS
	5	0.032	SG	0.021	SG
>55 years (Age Code5)	1	0.848	IS	0.035	SG
	2	1.000	IS	0.380	IS
	3	0.253	IS	0.065	IS
	4	0.032	SG	0.021	SG

SCA: Subcarinal Angle, IS: Insignificant, SG: Significant.

significant for the age group 16-25 years and it was highly significant for the width-depth ratio of lower trachea of the age groups 26-40 years and >55 years, significant for 41-55 years age group and insignificant for 16-25 years age group in both sexes.

As ANOVA test was highly significant ($p<0.001$) for both length and width-depth ratio of the trachea, multiple comparisons were done between all the five age groups for both males and females using Tukey's test. The results of multiple comparison tests in relation to length and width-depth ratio of upper and lower trachea were furnished in Table-1.

The mean length of the right principal bronchus found in this study were 2.02 cm, 2.39cm, 2.56cm, 2.52 cm and 2.6 cm in males and 1,8 cm, 2.3 cm, 1.96cm, 1.98 cm and 2.02 cm in females respectively in the 0-15 years, 16-25 years, 26-40 years, 41-55 years and >55 years age groups respectively.

The mean length of the left principal bronchus similarly were 4.4 cm, 5.11cm, 5.29 cm, 4.7 cm and 5.38 cm in males and 3.55 cm, 4.38cm, 4.03cm, 3.9 cm and 3.98 cm in females respectively in the 0-15 years, 16-25 years, 26-40 years, 41-55 years and >55 years age groups respectively.

The average transverse diameters of the right and left principal bronchi in our study was

1.6 cm and 1.5 cm respectively in both sexes.

The mean width-depth ratio in our study was1.16, 1.36, 1.27, 1.24 and 1.18 in males and 1.36, 1.42, 1.36, 1.32 and 1.28 in females for the right bronchus in the 0-15 years, 16-25 years, 26-40 years, 41-55 years and >55 years age groups respectively. The same were 1.22, 1.36, 1.32, 1.15 and 1.25 in males and 1.36, 1.47, 1.45, 1.18 and 1.21 in females for the left bronchus in the 0-15 years, 16-25 years, 26-40 years, 41-55 years and >55 years age groups respectively. It showed a decrease in the ratio from 0-15 years to 16-25 years age group. Thereafter it showed variable increase and decrease in the ratio.

The mean subcarinal angles in the 0-15 years, 16-25 years, 26-40 years , 41-55 years and >55 years age groups in our study were 64.3 degrees, 56.4 degrees, 58.4 degrees, 57.1 degrees and 59.5 degrees in males and 61.4 degrees, 52.9 degrees, 49.2 degrees, 48.2 degrees and 54 degrees in females respectively.

According to the independent samples test for the length of the bronchi, the p value was insignificant in the 16-25 years age group while it was highly significant in all the other groups for the right bronchus in both the sexes. The same was highly significant in all the groups for the left bronchus in both sexes.

The independent samples test for the width-depth ratio of the bronchi showed significant p values for all the age groups for the right principal bronchus in male and female.

The p value was highly significant for 16-25 years and 26-40 years age group and was insignificant in the other age groups for the left principal bronchus in both sexes.

The independent samples test for subcarinal angle showed highly significant p value in all the age groups except >55 years gae group which showed a significant p value.

As ANOVA test was highly significant ($p<0.001$) for both length and width-depth ratio of the right and left principal bronchi and subcarinal angles, multiple comparisons were done between all the five age groups for both males and females using Tukey's test. The results of multiple comparisons test in relation to length and width-depth ratio of lumen of right and left principal bronchi in male and female and subcarinal angles were furnished in Table-2-4 respectively.

DISCUSSION

Measurements of different dimensions namely length, antero-posterior (AP) and transverse (Tr) diameters of trachea vary from study to study. However, Engel[9] (1962) proposed the following measurements: -

Age	Average Length (cm)	Average AP Diameter (mm)	Average Tr Diameter (mm)
0-1months	3.8	5.7	6.0
1–3 months	4.0	6.5	6.8
3 –6 months	4.2	7.6	7.2
6–12months	4.3	7.0	7.8
1 – 2 years	4.5	9.4	8.8
2 – 3 years	5.0	10.8	9.4
3 - 4 years	5.3	9.1	11.2
6 - 8 years	5.7	10.4	11.0
10 –12years	6.3	9.3	12.4
14-16years	7.2	13.7	13.5
ADULTS	9.15	16.5	14.4

In the present study, the length of the trachea did not exceed 11.2cm in adults. It was also seen that both in male and female, the length of the trachea increased from 0-15 years age group to 15- 25 years age group which was also observed by Croteau *et al*[10] who stated that the tracheal length showed greater relative change in younger subjects. It might be due to the fact that this period is the growing period of life. From 41-55 years to 55 years and above there was a slight decrease in tracheal length in both male and female, which might be due to the contraction by more fibrous tissue present in this age group.

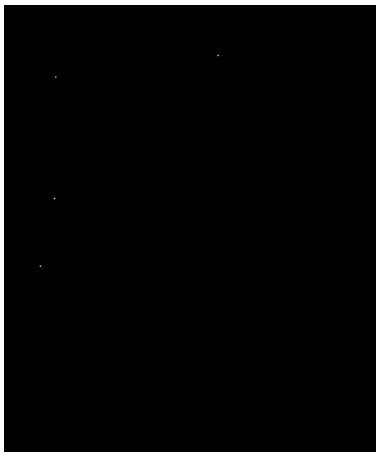

Fig. 1. Luminal shape (as a mark of width-depth ratio of the lumen) of upper trachea (UT), lower trachea (LT), right principal bronchus (RB) and left principal bronchus (LB) in six different specimens. (Specimen no., age and sex are depicted at the left margin of the figure).

According to Standring *et al*,[2] the external transverse diameter of trachea is 2cm in adult males and 1.5cm in adult females while its internal transverse diameter (lumen) is 12mm (1.2 cm) in live adults although this increases after death due to relaxation in the smooth muscles at its posterior aspect. In our study, the average external transverse diameters of upper trachea were 2.03 cm and 1.6 cm and of lower trachea were 2.02cm and 1.6 cm in adult males and females respectively, whereas the average internal transverse diameters of upper trachea were 1.24 cm and 1.22cm and of lower trachea were 1.2 cm and 1.1 cm in adult males and females respectively.

In the three and half year old female child in our study, the length, transverse and anteroposterior diameter of trachea were 5.4 cm, 1.2 cm and 0.9 cm respectively. This was in accordance to Engel,[9] whose values were 5.3cm, 1.12cm and 0.91 cm respectively.

Regarding the width depth ratio of the upper part of the trachea, it was seen that the ratio was variable (increase or decrease) at different age groups of male and female. One similarity was seen that the ratio decreased from 0-15 years to 16-25 years age group in male and female. This might be due to the fact that in this age group, there is increase in the angulations of the thyroid cartilage, which affects the luminal shape of the upper part of the trachea.

Regarding the width-depth ratio of the lumen of the lower part of the trachea, the ratio decreased from 0-15 years to 15-25 years age group in both male and female in our study.

The width-depth ratio of the lumen of the lower part of the trachea should be higher in 0-15 years age group than the other groups as in this age group, the width

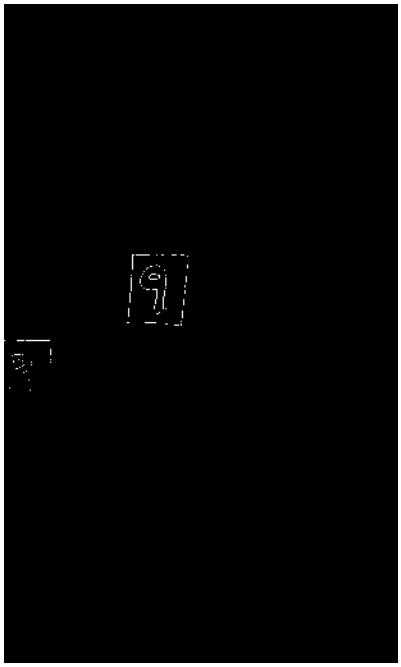

Fig. 2. Subcarinal angle of a 25 year old male (Specimen no. 9), R: Right side of specimen. Subcarinal angle: 67°.

(transverse diameter) of the lumen should exceed the depth of the lumen as the two principal bronchi are more wide apart, particularly up to the age of 3 years making an angle of 110 degrees as stated by Adriani *et al*.[11]

The difference in the width-depth ratio of the upper and lower part of the trachea might also be explained by the fact that the upper part of the trachea is under the influence of the atmospheric pressure and the lower part is under the influence of intrapleural pressure.[12]

According to Standring *et al*[2] the average length of the right and left bronchi are 2.5 cm and 5.5cm respectively, which was in accordance to our study.

The average transverse diameters of the right principal bronchi in our study were 1.62cm and 1.46cm and those of left principal bronchi were 1.66cm and 1.16cm in males and females respectively. This was in accordance to Standring *et al*,[2] who stated that the coronal diameter of the right main bronchus is about 17±4mm in men and about 15±4mm in women; the corresponding diameter on the left side is 2-3mm less.[13]

Considering the width-depth ratio of the right and left principal bronchi, it is seen that the ratio was variable in different age groups in both the sexes.

The length and diameters of the trachea and principal bronchi should be known accurately for selection of the bronchoscope of proper gauge for persons of different age groups of both sexes. Hence, the data obtained in the present study will be helpful to the bronchoscopists for skillful and expert contemplation of various diagnostic and therapeutic maneuvers using bronchoscopes without producing any undue complications.

Regarding the subcarinal angle, it is positively not same in the cadaver and in the living condition, due to the relative position of active and inactive diaphragm as observed by Fearson.[14]

In our study, the mean subcarinal angle decreased from the value of 64.3 degree and 61.4 degree in male and female respectively in the 0-15 years to 56.4 degree and 52.9 degree in male and female in the 16-25 years age group. This might be due to the fact that in 0-15 years group, the lung grows more laterally than downwards as the lateral chest wall is more yielding (ossification of the ribs are in immature stage). In the 16-25 years age group, the chest wall becomes relatively rigid as ossification of the ribs are about to be complete and direct the more downward growth of the lung causing the subcarinal angle to be narrower.

Haskin *et al*[15] measured the subcarinal angle of 100 autopsy specimens **(**47 men and 53 women of 21-80 years age**)**. In their study, the mean subcarinal angle for males was 62.0 degree; SD = 11.97 degree and the mean subcarinal angle for females was 60.9 degree; SD = 10.99 degree.

The knowledge of the subcarinal angle is of clinical importance due to the following reasons:

1. Bronchoscopy is easier in adults than neonates and children as stated by Fewell *et al*,[16] it requires more skill to introduce the bronchoscope particularly on the left side where the primary bronchus makes a smaller angle with the trachea. Lack of this knowledge might give a wrong interpretation of bronchial obstruction on failing to introduce the bronchoscope. 2. The growth in the mediastinal structures or any pathology of the lung or pleura (example: fibrosis, collapse, pleural effusion) may alter the subcarinal angle considerably.

The subcarinal angle contributed by the right bronchus is small, as it is more or less in the same line with the trachea. So lodgment of foreign body is more in right bronchus.[4]

In the present investigation, it was noted that there was a wide variation in different dimensions of the trachea, right and left principal bronchi and the subcarinal angle, in a same age group as well as in different age groups in both sexes. The study of these morphometric variations is helpful for the clinicians to understand the etiology of several airway diseases. The same is immensely important for the surgeons who deal with resection and reconstruction of the tracheobronchial tree. This knowledge has potential applications to studies in

pulmonary physiology and anesthesiology as also to conduction of some maneuvers like endotracheal intubation and bronchoscopic procedures (diagnostic, therapeutic and combined) with skill and perfection.

REFERENCES

1. Spencer S, Galloway H. Schwartz's Principles of Surgery. In Chest wall, Pleura, Lung and Mediastinum. Rusch VW and Ginsberg RJ (edrs). 7th edition. Churchill Livingstone. Edin. London 1999: 764.
2. Standring S. Ellis E, Healy JC, Johnson D, Williams A. Gray's Anatomy. In Thorax. Johnson D. (edr), 39th edition, Churchill Livingstone, Edin. Lon. Phil 2005: 1063-82.
3. Jit H, Jit I. Dimensions and shape of the trachea in the neonates, children and adults in northwest India. *Indian J Med Res* 2000; 112: 27-33.
4. Hasleton PS. Spencer's Pathology of the Lung. In Anatomy of the lung. Hasleton PS and Curry A (edrs). 5th edition. Vol. 1.McGraw-Hill 1996: 6-7.
5. Bonneli I, Besson A, Acuna RT. Variation of shape of large airways. *J Thorac Cardiovasc Surg* 1963; 82: 765.
6. Campbell AH, Liddelow AG. Significant variation in the shape of trachea and large bronchi. *Med F Aust* 1967; 54: 1017-20.
7. Fraser R, Muller N, Colman N, Pare P. Fraser and Pare's. Diagnosis of the diseases of the chest. In Investigative Methods in chest disease. 2nd edition. Vol. 1. Saunders. Phil 1999: 56.
8. Turner RS. A note on geometry of tracheal bifurcation. *Ant Rec* 1962; 143: 189.
9. Engel S. Lung Structure. In child's lung. thomas CC (edr), Springfield, USA. 1962: 6-9.
10. Croteau JR, Cook CD. Volume-pressure and length-tension measurements in human trachea and bronchial segment. *J Appl Physiol* 1961; 16: 170-2.
11. Adriani J, Griggs TS. An improved endotracheal tube for pediatric use. *Anesthesiol* 1954; 15: 466-70.
12. Proctor DF. The upper airway: The Larynx and Trachea. *Ann Rev Resp Dis* 1977; 115: 315-42.
13. Brock RC. The Anatomy of the Bronchial Tree. *AMA Arch Otolaryngol* 1958; 68: 454-9.
14. Fearson B, Whalen JS. Tracheal dimension in living infants. *Ann Otol* 1967; 76: 964.
15. Haskin PH, Goodman LA. Normal Tracheal bifurcation angle: A Reassessment. *Amer J Radiol* 1982; 139: 879-82.
16. Fewell J, Arrington R, Seibert J. The effect of head position and angle of tracheal bifurcation on bronchus catheterization in intubated neonate. *Pediatr* 1979; 64: 318-20.