

# A Study On Measurement Of Transverse Internal Diameter Of Trachea At C<sub>6</sub> Vertebral Level By Computed Tomography And Its Clinical Implications

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## Abstract

**Aim:** To study the measurement of transverse internal diameter of trachea by CT scan in patients and to compare the parameters between males and females.

**Methods:** This prospective study performed at Bankura Sammilani Medical College, Bankura, India, over a period of 1 year and 6 months from January 2015 to June 2016. 100 patients were selected among which 63 were male and 37 were female.

**Results:** Data of 100 participants were analysed out of which 63% were males & 37% were female. Majority (35%) of study subjects belonged to the age group of 11-20 years. From the results of the analysis it was clear that the influence of gender was found to be consistent throughout all the age groups i.e. female had a comparatively lower TIDT than that of the male. Scatter plot/Dot diagram between age and TIDT for the higher age group was revealed to be helpful for us to understand the influence of age on TIDT in the higher age group. It showed that only 3 percent variation in outcome variable (TIDT) could be explained by variation in input variable (age). Straightline equation ( $y=1.28+9.61E-4*x$ ) showing a huge error component (E) indicated that in this age group role of age on TIDT was insignificant. Age played a positive role in the TIDT up to the age of 21 years and gender was shown to have role in all age groups.

**Conclusion:** CT is a relatively accurate and safe way to measure the transverse internal diameter of the trachea.

**Keywords:** trachea, intubation, radiograph, prospective, normal range, multiple detector computed tomography.

## INTRODUCTION

Endotracheal intubation is essential for airway maintenance and adequate ventilation<sup>1</sup> to carry out several operative procedures usually without any complications. The oversized endotracheal tube relative to trachea or over-inflated cuff<sup>2</sup> between tube and anatomic structures, may damage the tracheal mucosa by friction and compressions, can cause airway edema, post - extubation stridor, subglottic stenosis<sup>3</sup> or cartilaginous ischemia<sup>2,4</sup>, especially in young age group. On the other hand, the smaller sized endotracheal tube will increase the resistance to gas flow, difficulty to smooth

ventilation, poor monitoring of end tidal gas<sup>5</sup> and risk of aspiration<sup>6</sup>. The level of cricoid cartilage, being the narrowest diameter of upper trachea, plays an important role for selection of the appropriate size of ETT.

To avoid repeated laryngoscopies and minimizing the risk of trauma<sup>7</sup> due to endotracheal intubation, the pre-anaesthetic assessment of transverse internal diameter of trachea is essential to select the appropriate sized ETT during intubation. It is thought to be important to select the appropriate size of ETT to prevent ETT-induced complications<sup>8</sup>, such as airway edema<sup>1</sup>. An overinflated cuff or excessively large ETT relative to tracheal size may induce tracheal mucosal ischemia<sup>2</sup> or hoarseness<sup>9</sup>.

Chest X-ray images, however, are often taken pre-operatively, and used to evaluate the diameter of the trachea so as to determine the tracheal tube size. However, the tracheal diameter measured by X-ray (TD-XP) and Ultrasonography are not always accurate. Tracheal diameter can be measured accurately by CT<sup>7,10-13</sup>. Previous studies have been attempted to evaluate the correlation of TD-XP and TD-Ultrasonography<sup>14-16</sup> with age, height, and weight<sup>17</sup> as a means of making approximate predictions of tracheal diameter.

## **MATERIALS AND METHODS :**

This prospective study performed at Bankura sammilani Medical College, Bankura, India over a period of 1 year and 6 months from January 2015 to June 2016. 100 patients were selected among which 63 were male and 37 were female. Written informed consent were taken from all selected cases before being included in the study. Selected patients were divided into age groups ;  $\leq 10$  yrs, 11-20 yrs, 21-30 yrs, 31-40 yrs and  $\geq 41$  yrs. Measurement of TD-CT at the level of C<sub>6</sub> vertebra. TD-CT was measured twice for each patient and the average was taken to alleviate bias.

### **Inclusion criteria :**

- i) Patients, who are undergoing CT scan in hospital for investigation of diseases such as cervical spondylosis , trauma etc. without any airway pathology.
- ii) Patients who underwent CT scan of the neck at hospital for trauma or CVA.
- iii) Patients who were scheduled to undergo spiral chest CT scan for medical diagnosis or health screening.

### **Exclusion criteria :**

- i) Patients showing airway pathology such as tumors or extrinsic compression.
- ii) Inherited or acquired abnormalities that might cause narrowing of the airway including all of the following: respiratory symptoms and signs (cough, wheezing, or stridor) , a history of sternotomy , tracheotomy.

### **Study Tools:**

1. Dual-source computed tomography (DSCT; SIEMENS Medical System , 16 slice Somatom Emotion , Germany).
2. Stand-alone workstation (Syngo™ ; SIEMENS Medical System, 16 slice Somatom Emotion, Germany).
3. CD – Cassette
4. Laptop
5. Endotracheal tube

Statistical analysis the calculations were carried out in SPSS. Linear regression were used.

## **RESULTS**

Data of 100 participants were analysed out of which 63% were males & 37% were female. Average age was estimated to be  $27.25 \pm 17.85$  (mean  $\pm$  sd) years with a median of 21 years and a range of 5-77 years. Majority (35%) of study subjects belonged to the age group of 11-20 years. However, one fourth of participants were from higher age group i.e. 41 years and above.

**Table : Distribution of male& female subjects according to age group:**

	≤10 yrs	11-20 yrs	21-30 yrs	31-40 yrs	≥41yrs
Male	7	19	6	9	19
Female	7	16	5	5	7

**Table: Distribution of participants as per their age groups and TIDT (N=100)**

Age group [yrs] (category)	Number (%)	TID-T (cm) mean±sd	F (ANOVA),p at df 4
≤10 (0)	14(14.0)	0.91±0.15	42.076, 0.000
11-20(1)	35(35.0)	1.19±0.12	
21-30(2)	11(11.0)	1.31±0.08	
31-40(3)	14(14.0)	1.34±0.05	
≥41(4)	26(26.0)	1.32±0.09	
Total	100(100)	1.22±0.18	-----

The tracheal internal transverse diameter was found to be higher in high age groups and the difference was statistically robust. But to explore the exact age group having significant higher or lower diameter than their counterparts the Analysis of Oneway Variance (ANOVA) was done with Post-hoc (LSD) test.

ANOVA revealed that the tracheal diameter was significantly smaller in the lower age groups i.e. group '0' and group 1 below 21 years beyond which no such differences could be revealed across the age groups i.e. between age groups 2,3 and 4. It meant that the TIDT increased up to the age of 21 years after which its enlargement was nil or negligible giving rise statistically insignificant difference across the age groups 2, 3, and 4. Whatever differences were observed between these higher age groups was seemed to be due to individual variation and or small sample size of each group.

**Table: Distribution of study subjects as per age groups and tracheal diameter (N=100)**

Age group(yrs)	TID-T in cm (mean±sd)	Unpaired 't' test, p at df 98
<21 (n <sub>1</sub> =49)	1.11±0.18	7.699, 0.000
≥21(n <sub>2</sub> =51)	1.32±0.08	
Total (N=100)	1.22±0.18	-----

Now, after creating two categories i.e. below 21 years (gr.1) and 21 years and above (gr.2) it was shown that the TIDT significantly differed across the group with smaller in the lower age group.

**Table: Distribution of study subjects as per gender and tracheal diameter (N=100)**

Gender	TID-T in cm (mean±sd)	Unpaired 't' test, p at df 98
Male (n <sub>1</sub> =63)	1.28±0.14	4.89,0.000
Female (n <sub>2</sub> =37)	1.12±0.19	
Total (N=100)	1.22±0.18	-----

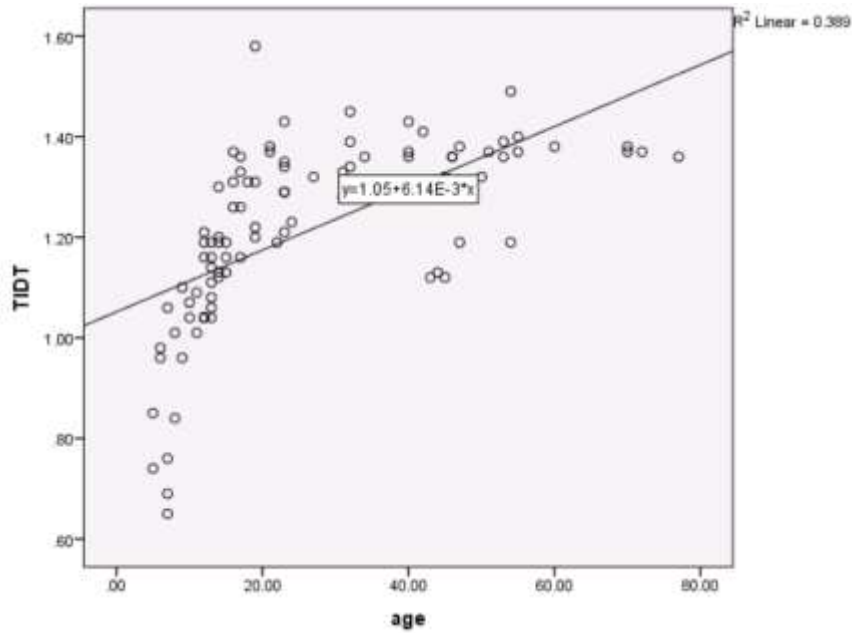
Further analysis showed that the male subjects had higher internal transverse diameter of trachea and the difference was revealed to be statistically robust.

**Table: Distribution of participants according to the TIDT in respect of age group and sex (N=100)**

Age group	Gender	TID-T in cm (mean±sd)	Unpaired 't' test, p,df
<21 years	Male (n <sub>1</sub> =27)	1.18±0.15	3.494,0.001,47
	Female (n <sub>2</sub> =22)	1.02±0.17	
≥21 years	Male (n <sub>1</sub> =36)	1.35±0.05	3.986,0.000,49
	Female (n <sub>2</sub> =15)	1.26±0.10	

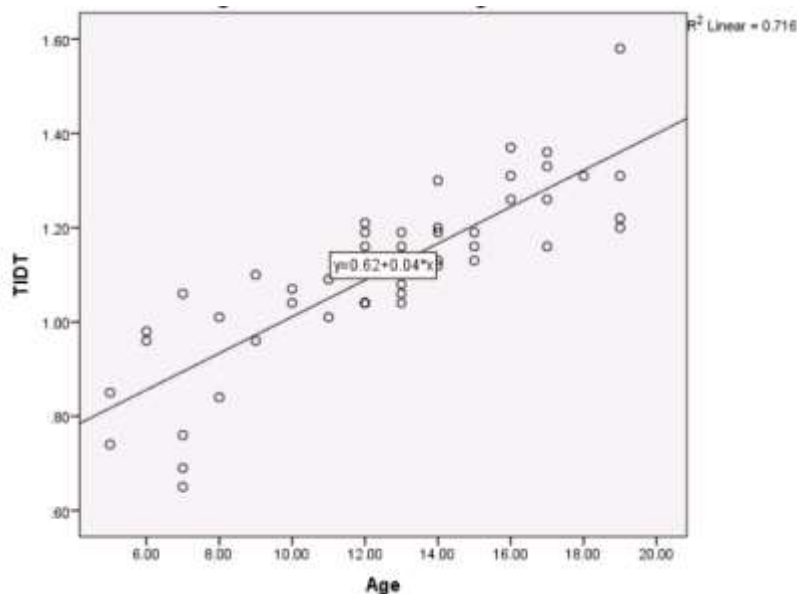
From the results of the analysis given in the above table it was clear that the influence of gender was found to be consistent throughout all the age groups i.e. female had a comparatively lower TIDT than that of the male.

**Figure: Correlation between age & TIDT**



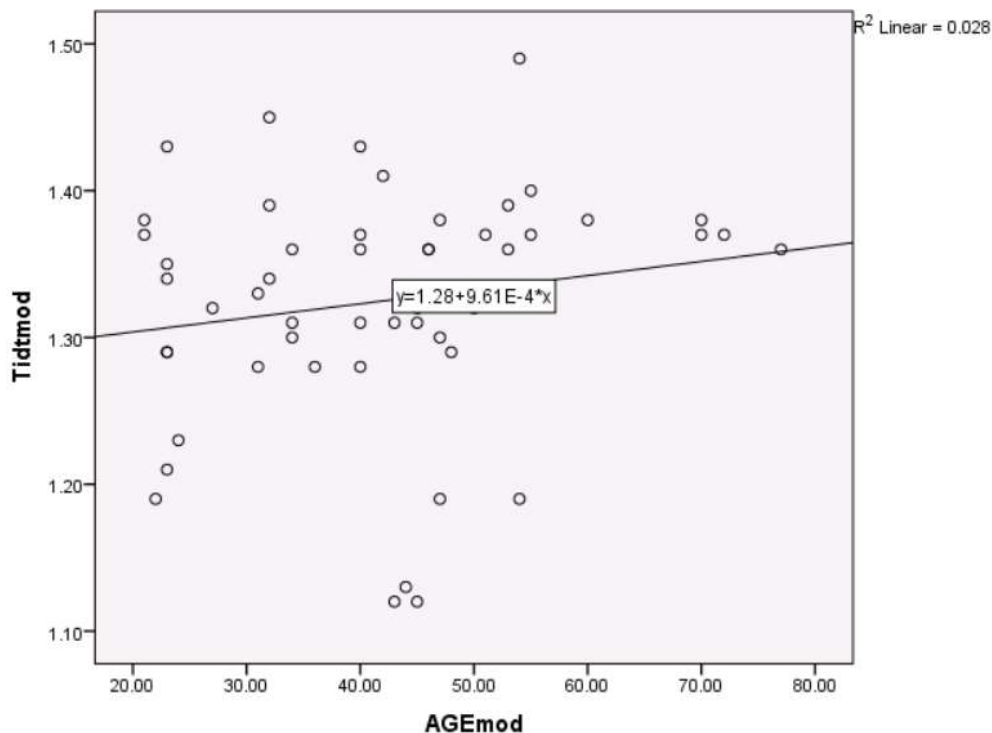
The figure reflected that the age had a positive correlation with TIDT explaining almost 39 percent variation in TIDT. But the huge error in the equation of straight line ( $y = 1.05 + 6.14E-3 * x$ ) was found to be an obstacle in interpretation.

**Figure Correlation between age and TIDT**



Similar analysis for the lower and upper age groups showed a comparatively clear picture. Figure reflected that almost 71 percent of variation in TIDT was explained by increasing age in the lower age group. The straight line equation ( $y=0.62+0.04*x$ ) was also very clearcut without any error component.

**Figure: Correlation between age and TIDT in higher age group**



Scatter plot/Dot diagram between age and TIDT for the higher age group was revealed to be helpful for us to understand the influence of age on TIDT in the higher age group. It showed that only 3 percent variation in outcome variable (TIDT) could be explained by variation in input variable (age). Straightline equation ( $y=1.28+9.61E-4*x$ )

showing a huge error component (E) indicated that in this age group role of age on TIDT was insignificant. The above three figures once again reaffirmed the role of age in the variation of TIDT.

At this juncture it was clear that age played a positive role in the TIDT up to the age of 21 years and gender was shown to have role in all age groups.

## DISCUSSION

Data of 100 participants were analysed out of which 63% were males & 37% were female. Average age was estimated to be  $27.25 \pm 17.85$  (mean  $\pm$  sd) years with a median of 21 years and a range of 5-77 years. Majority (35%) of study subjects belonged to the age group of 11-20 years.

According to Standring et al<sup>18</sup> 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 (1.2cm) in live adults although this increases after death due to relaxation in the smooth muscles at its posterior aspect.

In our study, the mean internal transverse diameter of trachea was  $1.22 \pm 0.18$  cm (N=100) at C<sub>6</sub> level.

Earlier studies have used radiographs as a method for obtaining tracheal measurements. Breatnach et al<sup>19</sup> measured the AP and transverse diameter of the trachea on posteroanterior and lateral x-rays of 808 adult subjects at a point 2 cm above the aortic arch. They found that in adult males of all ages, the AP diameter is consistently larger than the transverse diameter. That observation was not as strong in females, and the difference was significant only from the third decade on ward.

In the current study, we used CT scan as the method for tracheal measurement as it is non-invasive, well tolerated by patients, reproducible, which is the gold standard for tracheal measurements; by koletsis et al. The decision to use CT scan rather than radiographs was also influenced by a retrospective study by Sakuraba et al<sup>1</sup>, which has compared tracheal diameter obtained from chest x-rays and those using CT scans utilizing data of patients who underwent cervical vertebral laminectomy, in 146 patients who received both conventional chest radiographs and CT scans. The study found that measurements using x-rays didn't correlate with those using CTs and concluded that radiographs are not useful to select the appropriate size of ETT.

Only few studies have addressed nation-specific CT measurements of the trachea. A study conducted in New Zealand assessed tracheal morphometry in vivo using chest CT scans of 60 adult patients supplemented by measurements of 10 cadaver tracheas. Their measurements of maximum transverse diameters were done just above the Carina. Their results showed, mean transverse was  $25.7 \pm 3.7$  mm. That study has differed from ours by measurement of transverse internal diameter of trachea at the C<sub>6</sub> vertebrae (narrowest transverse internal diameter of trachea).

An Iranian prospective study by Zahedi-Nejad N et al<sup>20</sup> included 200 adult patients. Transverse diameter were obtained at two levels: right below sternal notch and right below the lower aspect of the aortic arch. They yielded a mean transverse diameter values were as follows, 18 mm in males and 14.9 mm in females. They compared their result with radiology text books. They concluded that Persian people tracheal measurements were close to those of the European people and attributed the apparent difference to the different measurement techniques.

Kumar and Ravikumar<sup>13</sup> produced similar work studying the internal diameters of the sub-glottic region and the trachea in the Indian population. It was a cross sectional observational study including 48 subjects who undergone neck and chest CT scans for reasons other than airway compromise. Their methodology differed in that they measured antero-posterior, transverse and circumference at various levels from 5 to 70 mm below the level of the glottis in the sub-glottic and upper trachea. The mean transverse diameter was 16.5 mm in males and 17.34 mm in females. They have concluded that dimensions of the sub-glottic region and trachea are less than that stated in the western literature and they have raised the question of whether they are using larger than needed endotracheal tube sizes.

Boiselle et al<sup>21</sup> studied tracheal collapsible in healthy volunteers during forced expiration using CT scans. In his study, he had compared tracheal diameters during inspiration and expiration. The diameters were obtained at two anatomic levels: 1 cm above the aortic arch and 1 cm above the carina. The study included 51 healthy adult subjects. We used the measurements obtained in inspiration to compare with our study even though Boiselle et al. did address the ethnicity of the studied population.

In this study we observed that the internal transverse diameter of trachea in females were comparatively smaller with statistically significant difference compared to males.

In comparison between our study and the previously mentioned studies, we found that mean transverse diameter in our study was  $12.2 \pm 1.8$  where as it was  $15.55 \pm 2.2$  mm in the Saudi subjects versus  $25.7 \pm 3.7$  mm in New Zealanders, the difference between means was 10.15. That difference was too large to be attributed to different measurement techniques.

In an effort to establish normal values for both investigational and patient care purposes, computed tomography was used to determine the length, diameters of the trachea's of 34 children up to the age of 6 years by Griscom et al<sup>10,7,11</sup>. The measurements were taken when patients were asleep. There was virtually no difference between boys and girls. The results were related to body height. But in our study, there was significant difference of transverse internal diameter of trachea at C<sub>6</sub> vertebral level i.e. 0.21 cm up to the age of 6 years (TID-CT in male = 0.93 cm and TID-CT in female = 0.72 cm).

In a study with 43 men, the transverse diameters (mean SD in millimeters) of the trachea at levels 1 and 2 were  $19.77 \pm 2.57$  /  $18.02 \pm 2.19$  respectively and in 34 women, those values at levels 1 and 2 were  $15.35 \pm 1.82$  /  $15.00 \pm 1.60$ , respectively. At both levels, transverse diameters were significantly greater in men than in women ( $p < 0.05$ ) in Korean adult population studied by Jae Youl Han et al<sup>12</sup>. They were divided into three age groups {group 1, 20-39 years ; group 2, 40-59 years ; groups 3,  $\geq 60$  years}. The transverse diameters of the trachea were measured at the level of the thoracic inlet {Level 1} and the aortic arch {Level 2}. These values obtained at each level were compared between age groups and sexes.

In our study, TID-T (cm) measured at the level of C<sub>6</sub> vertebrae and the results were

Age group	Gender	TID-T in cm (mean±sd)
<21 years	Male (n <sub>1</sub> =27)	1.18±0.15
	Female (n <sub>2</sub> =22)	1.02±0.17
≥21 years	Male (n <sub>1</sub> =36)	1.35±0.05
	Female (n <sub>2</sub> =15)	1.26±0.10

From the results of the analysis given in the above table it was clear that the influence of gender was found to be consistent throughout all the age groups i.e. female had a comparatively lower TIDT than that of the male. Data from different authors:

In our study, transverse internal diameter of trachea at C<sub>6</sub> level in females were comparatively and statistically less than males this is in agreement with most of the other studies.

We used CT scan as the modality of measuring the tracheal dimensions with several advantages. CT Images are not magnified by divergence of the X-ray beam, the technique of acquiring the scan and measuring is more easily standardized (supine position, head in neutral position, breath-hold at maximum normal respiration, etc.), and scans can be viewed in multiple planes which further help in precise measurements. It was found that the average internal transverse diameter of trachea in the Bankura population (Eastern India) was less than that reported in literature.

According to **R Chunder et al<sup>22</sup>**, on 87 specimens (51 male and 36 female) the average internal transverse diameters of upper trachea were 1.24 cm and 1.22cm in male and female respectively. In our study, internal transverse diameters of trachea at C<sub>6</sub> level were 1.28±0.14 cm and 1.12±0.19 cm in male and female respectively.

## CONCLUSION

There are significant differences in the internal transverse diameter of the trachea between men and women in normal Indian adults. CT is a relatively accurate and safe way to measure the transverse internal diameter of the trachea. Studies in collaboration with Radiologists, Anesthesiologists and Surgeons should be made to determine the rate of post-intubation complication and correlate with tube size used.

This study is helpful for the clinicians to understand the etiology of several airway diseases. It is also important for performing some maneuvers like endotracheal intubation with skill and perfection.

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