Original Article

Proper Tracheostomy Tube Bending Angle and Flange-to-Angle Length

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Background: In tracheostomies, the use of tubes with appropriate bending angles and flange-to-angle lengths (FtLs) is essential to avoid complications.

Objective: To assessed computed tomography (CT) scans of the normal anatomy of individuals to determine the appropriate bending angles and FtLs.

Materials and Methods: Three-hundred thirty-eight patients underwent CT between January 2012 and July 2018, and their neck anatomy, include larynx and trachea, could be clearly visualized. The bending angle and FtL were measured using the standard measuring tools. Data were analyzed. A p-value of less than 0.05 indicated significant differences.

Results: The median age was 53 years. The median body mass index was 21.16 kg/m^2 in men and 22.04 kg/m^2 in women. The median bending angle was 102° in both genders, and the difference between genders was not significant. The median FtL was 19.93 mm in males and 21.68 mm in females, and the difference between genders was significant ($U=10,461$, $z=-3.58$, $p<0.001$). The bending angle and FtL showed a statistically significant medium positive correlation.

Conclusion: Females had significant deeper tracheal area than males at 21.68 mm versus 19.93 mm. There was a positive correlation between the bending angle and the FtL. The median bending angle was 102° in both genders.

Keywords: Tracheostomy; Trachea; Intubation; Tracheostomy tube

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A tracheostomy involves opening the airway directly from the trachea to the anterior of the neck. Indications for tracheostomy are bypass airway obstruction, facilitation of long-term mechanical ventilation, tracheal suctioning, and aspiration prevention[1]. This procedure allows breathing without the use of the nose or mouth. Medical records first depicted tracheostomy dating back at least 3,500 to 3,600 years, in the time of Alexander the Great[2], and from documents from Egypt[3]. Antonio Musa Brasavola documented a successful operation and published his accounts in 1546[4]. Early operations aimed at relieving obstructions. The current techniques described by Chevalier Jackson in the early twentieth century emphasized risk reduction and decreased complication rates to under 2%.

Improper tube bending angle and flange-to-angle length (FtL) can result in a wide range of complications. If the tube is too short, the angle of the tube may be positioned in the stromal tissue, with the tip of the tube directed toward the membranous posterior tracheal wall and could easily dislodge[5,6]. A narrow tracheostomy angle risks injuring the innominate artery[7], which results in life-threatening bleeding. A wide angle also injures the tracheal mucosa, producing an uncomfortable sensation.

Tracheal and neck anatomy differ across individual. Since the human anatomy differs by race[8], the proper anatomic considerations for tracheostomies may differ for patients of different races. However, no previous studies have attempted to address these parameters in Asian. The present study aimed to determine the appropriate bending angle and FtL in the Thai population. The authors presented the following article in accordance with the STROBE reporting checklist.

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Materials and Methods

The present study was a descriptive, cross-sectional study that measured the bending angle and the FtL of adult patients, aged 18 years and over, between January 2012 and July 2019. The present study was conducted at the Faculty of Medicine, Chulalongkorn University and King Chulalongkorn Memorial Hospital, Thai Red Cross Society (Bangkok, Thailand). The definitions of bending angle and FtL are depicted in Figure 1.

The present study included adult patients aged at least 18 years old that underwent computed tomography (CT) scans in the neutral supine position, which clearly visualized the anatomy of the larynx and trachea. The midline tracheal point needed to be identified by comparing the midline between the axial and sagittal views from the CT scan using the midline sagittal view. Patients with any pathology at the larynx, trachea, or anterior neck and those who had previously undergone tracheostomy were excluded. The protocol for measurement involved the following steps, 1) acquire midline axial and sagittal views, 2) draw the sagittal line at the middle of the trachea, 3) draw the perpendicular line parallel to the anterior skin of the neck according to the location of the tracheostomy incision, and 4) measure the angle at the intersection between the two lines, and measure the length as the distance from the skin to the intersection point. Measurements were performed using the standard measuring tool in the Synapse® (FUJIFILM Medical Systems USA, Inc.) software. The measurement were performed three times before calculating the average value by single author (KS).

Sample size calculations were performed for the survey research. The authors set Z to a 95% confidence interval, the acceptable margin of the angle error as 1°, and the depth error as 1 mm. After the pilot study, the authors identified a standard deviation of 9.33. The sample size needed was 334 for FtL and 216 for depth, thus, 338 cases were needed for the present study.

Data were analyzed using IBM SPSS Statistics, version 20.0 (IBM Corp., Armonk, NY, USA). Normality was assessed using the Kolmogorov-Smirnov test because the sample size was larger than 50. The authors used descriptive analysis showing categorical variables in frequency and percentage of gender, analytical statistical analysis of relationships among gender, FtL, and bending angle. Student's t-test or Mann-Whitney U test was used to assess the angle in relation to gender. A Pearson correlation or Spearman's rank correlation was used to assess the correlations of the FtL depth and bending angle. A p-value of less than 0.05 indicates a significant difference between variables.

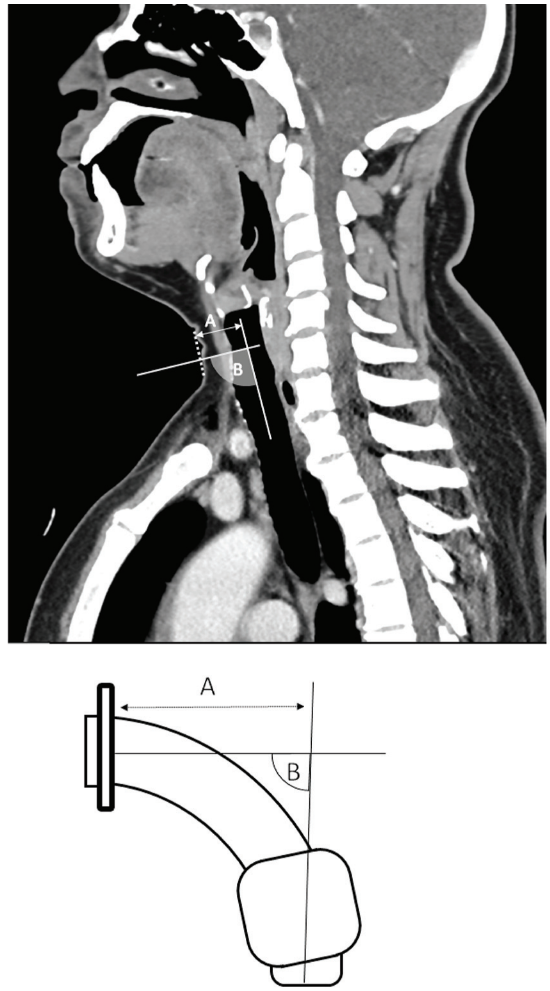

Figure 1. Definition of the flange-to-angle length (A) and bending angle (B).

The study was conducted in accordance with the Declaration of Helsinki. The present study was approved by the Institutional Review Board of the Faculty of Medicine, Chulalongkorn University (IRB No. 017/60). Access to medical records and radiological data were granted by the Dean of the Faculty of Medicine, Chulalongkorn University, and the Director of the King Chulalongkorn Memorial Hospital. The present research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Results

Images from 338 patients, involving 206 men

Table 1. Demographic characteristics and measurement results

	Male	Female
No. of patients	206	132
Median BMI	21.16	22.04
Age (years)		
Median	53	53
IQR	16 (64, 48)	22 (64, 42)
Bending angle		
Median	102	102
IQR	10 (106, 96)	12.25 (107, 94.75)
Flange-to-angle length		
Median	19.93	21.68
IQR	5.16 (24.2, 19.03)	6.3 (23.3, 17)

IQR=interquartile range

Table 2. Results of the Mann-Whitney U test

	Bending angle	FtL
U test	13,524	10,461
z-score	–0.082	–3.577
p-value	0.935	<0.001

FtL=flange-to-angle lengths

and 132 women, were included in the study. The median age of both male and female participants was 53 years, ranged from 18 to 88 years. Body mass index (BMI) was 21.16 and 22.04 kg/m² in men and women, respectively. The Kolmogorov-Smirnov test indicated that the bending angle and FtL did not follow a normal distribution for men and women (D[338]=0.068, p=0.001 and D[338]=0.061, p=0.004, respectively). The median angle was equal between genders with absolute values and interquartile ratios shown in Table 1.

Mann-Whitney test (Table 2) indicated that the difference in the median angles between genders was not statistically significant (U=13,524.5, z=–0.8, p=0.935). In contrast, the FtL was longer in females than in males, and Mann-Whitney test indicated that this difference was statistically significant (U=10,461, z=–3.58, p<0.001). Pearson correlation analysis was performed to determine the relationship between the bending angle and FtL, and the two variables showed a statistically significant medium, positive correlation (r=0.371, n=338, p<0.001).

Discussion

The present study examined the proper bending angle and FtL. To the authors knowledge, this is the first study on this topic, especially in the context of Asian neck anatomy, which is obviously different from the neck anatomy in people of Western ethnicities. Asian people tend to have a lower average BMI[8,9], reflected by a median BMI of approximately 21 kg/m² in the present study, and were presumed to have a longer neck and lesser subcutaneous neck fat. Studies have found a correlation between BMI and neck circumference, and a higher BMI is associated with a higher neck circumference[10,11]. These factors could lead to more superficial tracheae, a shorter FtL, and a more acute bending angle. Thus, tracheostomy tubes designed for the Western population may not properly fit Asian patients and lead to tracheostomy tube-related complications.

The standard tracheostomy tube description includes the inner cannula diameter, outer cannula diameter, total length, and bending angle. The diameter can be referenced by either the Jackson or International Organization for Standardization (ISO) sizing methods. The FtL varies with the tube design and manufacturers, and, as a rule of thumb, larger-diameter tubes usually have longer FtL lengths. The authors reported the ideal FtL is approximately 20 mm for patients of both genders. Unfortunately, the FtL parameter was not included in any of the tracheostomy tube descriptions. The authors believed that this parameter is also important for proper tube selection and should be made available.

Tracheostomy tubes can be divided into two major categories based on the tracheostomy tube bending angle, angled (acute bent tubes such as Portex Blue Line®) and curved (continuously curved tubes such as Shiley® or Tracoe Twist®). However, there is no consensus regarding the best tube angle design. Studies suggest that an angled tube may better conform to the airway anatomy and cause less pressure on the tracheal stoma than curved tubes because the trachea is essentially straight[12].

There are various methods for evaluating the different variations in airway anatomy. Corbett et al[13] developed a four-point scoring system based on chest radiograph measurements to predict a larger than standard tracheostomy tube. Szeto et al[14] showed that the range of trachea-to-skin soft tissue thickness in obese patients could be predicted using simple anthropometric tape. Pandian et al[15] used matched case-control study to recommend that clinicians should consider using non-standard tubes in male patients with endotracheal size of 8.0 or greater and a trachea-to-skin distance of more than 4.4 cm on CT scan.

Improper size, length, and angle of the

tracheostomy tube can lead to complications. Schmidt et al[16] performed a retrospective study in an acute care unit and reported a 10% incidence, or 40 out of 403 cases, of tube malpositioning in bronchoscopy examination, and 92% of these were caused by impingement of the posterior tracheal wall occluding the distal tip of the tracheostomy tube. The tracheal mucosa may show ulceration, exposed tracheal cartilages, and pressure necrosis, and more severe and fatal complications such as trachea-innominate fistula or trachea-esophageal fistula[17]. Excessively small tubes can increase respiratory effort and the risk of accidental decannulation. In contrast, excessively large tubes can cause patient discomfort and may lead to tracheal damage as mentioned above[18].

A previous study by Ghosh et al[19] assessed the bending angle in patients in India using silver tubes. CT scans were used to perform measurements in 20 patients, with an average age of 45 to 55 years, all of whom had airway obstruction from laryngeal cancers and underwent a tracheostomy, and a proper angle was found at 112°. The authors tailored a specific tracheostomy tube from the measured angle and used it for their patients. Coughing, dysphagia, tube dislodging, and contact between the distal tube and the posterior tracheal wall did not occur with the 112° tube, unlike the tubes with 120°, 125°, and 130° angles. The study by Mallick et al[20] also recommended a bending angle of 110° to 120°. In the present study, the median bending angle was approximately 100° in both genders, and the maximum angle was approximately 120°. Physicians should consider this whenever using a tube with bending angle more than 120°, especially in patients of Asian ethnicities.

The design and materials of the commercial tracheostomy tubes vary. The authors have compared the technical data of the bending angles of different commercially available tubes in Table 3. Portex Blue Line Ultra® is a commonly used tube with a fixed angle of 105°, while in Shiley Flexible® and Tracoe Twist®, the bending angle changes slightly according to the tube size. Selection of tracheostomy tubes with appropriate lengths and angles is important and can prevent early and long-term complications.

The present study had limitations owing to the non-normal distribution of the sample size. Thus, the measured values may not sufficiently represent the true population of Thailand. A larger sample size may address this limitation. Moreover, the decrease in complications using the proposed angles can only be presumed and requires clinical evidence. Further clinical studies are essential to validate these findings.

Table 3. Comparison of bending angles among different commercially available tubes

Tube	Angle (°)
Shiley Flexible®	
5CN70R	79
7CN80R	88
9CN90R	90
Portex Blue Line Ultra®	
7	105
8	105
9	105
Tracoe Twist®	
7	95
8	90
9	90

Conclusion

In the present study of 338 CT scans of Thai individuals, the bending angle was 102° in both genders. The FtL was 21.68 mm in females and 19.93 mm in males. Females showed a significantly deeper tracheal area than males. There was a positive correlation between the bending angle and the FtL.

What is already known on this topic?

Tracheal anatomy is individually different. Improper tracheostomy tube bending angle and FtL lead to tube-related complications.

What this study adds?

This report describes the bending angle was 102° in both genders and FtL was 21.68 mm in females and 19.93 mm in males. This parameter should help for better tube selection especially in Asian population.

Availability of data and material

Data available on request from the authors.

Authors' contributions

(I) Conception and design: all authors; (II) Administrative support: KS, NT; (III) Provision of study materials or patients: KS, NT; (IV) Collection and assembly of data: KS, NT; (V) Data analysis and interpretation: all authors; (VI) Manuscript writing: all authors; (VII) Final approval of manuscript: all authors

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Conflicts of interest

The authors report no conflict of interest

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