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Comparison of lung ultrasound technique *versus* clinical method to evaluate the accuracy of size and placement of left endobronchial double lumen tube in patients undergoing elective thoracic surgery: a prospective observational study

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Abstract

Anthropometric measurements like height and gender have been frequently found to be inaccurate in prediction of size of double lumen tube (DLT). A tracheal ultrasonography (TUS) is a technique that can be used to predict the size of DLT and its correct placement for lung isolation. We aim to check the accuracy of ultrasound over clinical methods. This prospective study included 68 patients undergoing elective thoracic surgery requiring one-lung ventilation (OLV) with DLT. The groups were assessed for the size of DLT by either anthropometric measurement using height and gender (Group C) or ultrasound method (Group U). Further, the accuracy of placement of DLT was assessed through, either lung auscultation in group C or various ultrasonographic and ventilatory parameters such as lung isolation in the first attempt (lung sliding and lung pulse sign), oxygenation status and peak airway pressure, in group U. Surgeon satisfaction score was also compared in both the groups. The accuracy of predicted DLT size between Group C and Group U was statistically significant (p=0.044). In Group C, 56% of patients showed a mismatch between the predicted DLT size and the actual size required, while in Group U, the mismatch was only 32.4%. The accuracy of DLT placement through group C was 41% as compared to 79% in Group U. Surgeon satisfaction score was also significantly higher in Group U as compared to Group C (p=0.0028). Thus, our study suggests that tracheal and chest ultrasonography for DLT size selection and placement for lung isolation is superior to clinical methods.

Key words: thoracic anesthesia; airway management; endobronchial double lumen tube; tracheal ultrasonography; lung ultrasound; anthropometric measurement; lung isolation

Introduction

Endobronchial double lumen tube (DLT) is commonly used for lung isolation in patients undergoing thoracic surgeries [1,2]. Selection of appropriately sized DLT is often based on anthropometry-based formulas, chest radiographs and spiral CT scan. Although pediatric FOB is the gold standard for confirmation of DLT placement, universal availability of equipment and skilled personnel becomes a limiting factor in a resource-limited area [3-5]. In such scenarios, anesthesiologists rely on clinical methods like auscultation of breath sounds with sequential clamping of both the lumens of DLT or chest radiograph to confirm the correct placement of DLT. However, auscultation may not always recognize the misplacement of DLT, with a reported incidence of 48% by blind methods [3]. A chest X-ray is usually not feasible in intraoperative settings, with the added disadvantage of undue radiation exposure.

Lung ultrasonography (LUS) is a non-invasive, bedside technique, often used to confirm the correct placement of the endotracheal tube and to identify the lung's respiratory movement [6].

There are limited studies on the utility of ultrasound in confirming the correct size or placement of DLT in resource-limited settings. With this research gap, we undertook this study with the primary objective of evaluating of accuracy of ultrasound trachea and lung in assessing the appropriate size and placement of DLT for lung isolation compared to the clinical method. Secondary outcomes were the time required for DLT placement, incidence of respiratory complications and satisfaction grading of lung isolation by the operating surgeon through direct observation.

Methods

It was a single-center, prospective, observational cohort study in which consecutive patients aged 18-75 years, of either sex, belonging to American Society of Anesthesiologists (ASA) physical status I, II or III, scheduled for elective thoracic surgery requiring one-lung ventilation (OLV) with left DLT, were recruited from January 2020 to March 2021 after Institutional human ethical committee approval (IHEC-LOP/2019/MD0084) and registration of the study under the clinical trial registry of India (CTRI/2021/04/042691). Written informed consent was given by all study participants for using anonymized data for scientific purposes. Patients with an anticipated difficult airway, tracheostomy, deranged pulmonary function tests, re-do surgery, and pneumothorax were excluded.

The consecutive patients fulfilling the inclusion and exclusion criteria were assigned alternately to two groups:

Group C: prediction of left DLT Size was based on the anthropometric measurement (height and gender) and assessment of correct placement of DLT was done clinically by auscultatory method by sequential clamping of both the lumen of DLT.

Group U: prediction of left DLT Size was done after assessing tracheal width by ultrasonography as suggested by Brodsky et al. [7] [Table.1] Correct placement of DLT for lung isolation was done using lung ultrasound.

Tracheal ultrasound: tracheal USG was done using a linear transducer of 6 - 13 MHz of ultrasound machine (SonoSite-M-Turbo) with the study participants placed in a supine position with slightly extended head. The scan was performed in a transverse plane with the transducer marker directed toward the patient's right and perpendicular to the skin over the cricoid cartilage. The transverse diameter of the column of air at the cricoid cartilage was measured, which suggests the size of a trachea, and accordingly, the appropriate size of DLT was chosen [Figure 1].

Lung ultrasound: the same USG machine and probe were used for LUS in 3 steps; i) both lungs were ventilated and confirmed with the "lung sliding sign"; the tracheal lumen was clamped, and only the left lung was ventilated, which was confirmed with a lung sliding sign on the left side and a "lung pulse sign" (signifies the collapse of the lung) on the right side; ii) the same process was repeated after clamping the bronchial lumen.

As per institutional protocol, after ensuring standard monitoring and securing large-bore intravenous access, anesthesia was induced. The trachea was intubated by an anesthesiologist with at least three years of experience with a left-sided DLT based on prediction as per group allocation. Intratracheal placement of DLT was confirmed by an end-tidal carbon dioxide (EtCO2) monitor. Lung isolation was confirmed as per methodology of the allocated group.

During bilateral lung ventilation, the lung was ventilated with tidal volume (TV) of 6-7 ml kg^{-1} with a fractional inspired concentration of oxygen (FiO_2) of 0.5. Once OLV was initiated, the TV was decreased to 4-5 ml kg^{-1} with positive end-expiratory pressure (PEEP) of 5 cm of H_2O. The respiratory rate was adjusted to maintain end-tidal carbon dioxide (EtCO2) of 35-45 mmHg.

Correct positioning in both groups was also ascertained by normal airway pressure and oxygenation during OLV. The time taken for placement of the DLT was measured from confirmation of tracheal intubation by capnograph after tracheal balloon inflation till the confirmation of satisfactory lung isolation.

Four parameters were assessed for the accuracy of lung isolation: i) lung isolation achieved at the first attempt; ii) normal peak airway pressure, which is defined as <35cm H_2O; iii) adequate oxygenation status defined as no need for intervention like continuous positive airway pressure (CPAP), increments in FiO_2 of more than 0.5 or PEEP of more than 5 cm of water to maintain saturation of more than 92%; iv) assessment grading was given by the operating surgeon (as “poor,” “good,” and “excellent”) by direct visualization of intraoperative lung isolation.

If at any point after DLT placement, there was a rise in airway pressure or inadequate oxygenation status, and/or poor surgeon’s satisfaction score, malposition of DLT was ruled out by intraoperative FOB-guided readjustment, with documentation of the same.

Statistical analysis

PASS 14 Power Analysis and Sample Size Software (NCSS, LLC. Kaysville, UT, USA) was used to determine the sample size with a 95% confidence interval and 80% power. Our sample size was 68 and with a 10% dropout rate, a total of 75 study participants were needed. Microsoft Excel and EPI-info version 7 software (Centre of Disease Control and Prevention, Atlanta, GA, USA) were used for data entry and analysis, respectively. Mean and standard deviation summarize numerical data when normally distributed, and count and percentage for summarizing nominal data. Contingency tables were prepared for the data. Categorical data was compared using the Fischer exact test and Pearson Chi-square test. Continuous data was compared using unpaired *t*-test. P-value, sensitivity, specificity and accuracy of each group was calculated using AUC-ROC curve. A p-value <0.05 was considered as significant.

Results

A total of 75 patients were enrolled in the study. However, 7 patients were excluded and final data analysis was done in 68 patients (Group C=34; Group U=34) [Figure 2]. Participants in Groups C and U were similar with respect to age, sex and height (Table 2).

DLT size

In Group C, estimated DLT size matched with the actual size requirement in 15 patients (44.0%). It was larger and smaller than that predicted in 8 (23.5%) and 11 (32.5%) patients, respectively. Thus, 56% of patients in group C showed a mismatch between the predicted and required DLT size. On tracheal USG, the mean tracheal width in males and females was observed as 15.85 and 14.56 mm, respectively [Figure 3]. In Group U, DLT size matched the actual size requirement in 23 (67.6%) patients. DLT size was larger and smaller than predicted in 5 (14.7%) and 6 (17.6%) patients, respectively. Thus, 32.4% of patients in group U showed a mismatch between the predicted and required DLT size. A statistically significant higher accuracy in predicting DLT size was observed in Group U as compared to Group C (p=0.044) (Table 3).

DLT placement

Successful lung isolation was achieved on the first attempt in 21(61.8%) and 29 (85.3%) study participants in groups C and U, respectively (p=0.028). The mean peak pressure was observed to be higher in Group C as compared to Group U (16.21 ± 0.98 vs 15.00±0.82; p=0.00001*)*. Three patients (8.8%) in Group C had an oxygen saturation of less than 92%, while in Group U, there were none (p=0.239). FiO_2 more than 0.5 was needed to maintain a saturation of 92% in 16 (47.1%) and 10 (29.4%) patients in Group C and Group U, though it was statistically insignificant (p=0.212).

Sensitivity, specificity, and predictive value

The sensitivity of lung USG (86%) was significantly higher as compared to clinical methods (52%) for assessment of DLT size, though the specificity of both the methods was low (25% and 18%, respectively). The overall accuracy for confirmation of correct DLT placement of clinical methods (41%) was lower as compared to lung USG (79%) (Table 5).

Complications with DLT placement

In group C, seven (20.6%) patients had sore throat, compared to four (11.8%) patients in group U. Though the difference was statistically insignificant, the ultrasound group had lesser complication. Trauma during intubation was not seen in any of the two groups. More than one intubation attempts were seen in 13 (38.2%) and 5 (14.7%) patients in Group C and Group U, respectively (p=0.0028) which was attributable to improper tube size.

Surgeon satisfaction score and rapidity of placement

In Group C, surgeons gave an acceptable and excellent satisfaction score in 20 (58.8%) and 12 (35.3%) patients, respectively. Poor satisfaction score was observed in 2 (5.9%) patients. In Group U, surgeons gave an excellent and acceptable satisfaction score in 7 (20.6%) and in 26 (76.5%) patients, respectively. A poor satisfaction score was seen in 1 (2.9%) patient only. The association between the surgeon satisfaction score and the groups was significant (p=0.0028). The mean duration from intubation to placement confirmation was significantly higher in Group C as compared to Group U (250 *versus* 192 sec, p<0.0001) (Table 4).

Discussion

In this prospective observational cohort study of 68 patients undergoing elective thoracic surgery requiring one-lung ventilation (OLV), we found that tracheal ultrasound had higher accuracy in prediction of DLT size than anthropometric formula-based methods. Lung ultrasound fared better in diagnostic accuracy, with higher sensitivity and surgeon satisfaction scores and faster confirmation of correct DLT placement.

Size of DLT

The optimal size DLT is the largest tube whose main body passes through the glottis without any trauma while the bronchial lumen fits the desired bronchus with only a small air leak when its cuff is deflated [8]. An inappropriately sized DLT can interfere with oxygenation, cause airway trauma and affects lung isolation during OLV [9]. The demographic parameters such as height and gender-based formulas used to predict the DLT size, may not be accurate, especially in Asians, who are generally smaller [8,10]. Brodsky *et al*. found that the average tracheal widths for Asian and non-Asian men were 19 ± 2 mm and 21 ± 2 mm, whereas that for women were 16 ± 2 mm and 17 ± 3 mm, respectively [8.]

In a previous study, the width of the trachea was measured in 70 patients at the level of the clavicles in a recent posteroanterior chest radiograph. They found average tracheal diameter for males was 22 mm (range 15-27 mm) and 17 mm (range 13-25 mm) in females [11]. However, in the present study, the average tracheal diameter in males and females was 15.85 mm (range 13-20 mm) and 14.56 mm (range 12.5-16 mm), respectively. The difference in the measured tracheal diameter can be due to different population characteristics of different areas. Further, in our study, the tracheal diameter was measured at the level of the cricoid cartilage, while Brodsky *et al*. measured the tracheal diameter at the level of the clavicle.

Considering anthropometric measurements of the Indian population, a DLT size 39 Fr for and 37 Fr are usually chosen for adult males and females, respectively. When assessed through the USG method, we could place a 41 Fr tube in two adult males and 35 Fr in one adult male, and 32 Fr in 1 adult female, using the tracheal diameter as a guide. Such varied size prediction is not possible with clinical methods, which ultimately causes difficulty in achieving proper lung isolation due to inappropriate-sized DLT. On the other hand, measurement of tracheal diameter with the help of ultrasound technique reduces the chances of inappropriate DLT insertion and time duration of DLT placement from intubation to tube fixation with the better achievement of OLV [12].

Direct measurement of tracheal width by imaging modalities like chest radiographs or ultrasound can be used to help predict the optimal size of DLT, independent of height and gender [10,13]. Due to lateral positioning in thoracotomy, an undersized DLT may easily advance too deep into the bronchus and obstruct the upper lobe orifice. In such cases, inflation of the bronchial cuff with a larger air volume could lead to cuff herniation or cuff rupture. If underinflated, the lungs will fail to collapse with unsuccessful lung isolation. The lumen of smaller DLT offers more resistance to airflow during OLV and makes it more challenging to advance the suction catheter and FOB. Conversely, if an oversized DLT is used, it may injure the airway [14]. Significantly better accuracy of the ultrasound technique was observed in predicting the optimum size of DLT as compared to the clinical method. Moreover, measurements are reproducible, with the benefit of no radiation exposure to the patients.

Confirmation of DLT placement

Clinical confirmation of proper DLT placement is done by inspecting chest wall movements and auscultating breath sounds. However, it is non-specific and less accurate [15] .Auscultation depends on the sensitivity of the stethoscope, hearing acuity of the individual, tidal volume, thickness of the chest wall, consistency of underlying lung tissue, and extent of underlying lung pathology. Conductance of sound from the other side of the chest confounds the auscultation of one side of the chest [15].

Ultrasound is a non-radiation, non-invasive, easy to learn and quick technique, often available in operation theatres. Limited studies have used sonographic prediction of DLT size and lung sliding sign in confirming the position of DLT [11].The concept of lung sliding, the sonographic observation of the movement of the visceral pleura against the parietal pleura, was first introduced by Lichtenstein in 1980 [16]. It depends on compliance and tidal volume and can be used for continuous ventilation monitoring. The accuracy of lung USG can be enhanced with the M-mode found on most ultrasound machines [17]. In M-mode, the presence of the lung sliding sign is visualized as the seashore sign, and the absence of lung sliding can be seen as the stratosphere sign [18]. In the non-ventilated or collapsed lungs, a lung sliding sign is absent, and the pleural line moves with heartbeats in a pulsatile manner known as the lung pulse sign. Lung pulse sign is 93% sensitive and 100% specific in identifying lung collapse [16]. Thus, if a sonographic demonstration of lung sliding on one side and lung pulse on the other side of the chest is present, then adequate functional lung isolation can be predicted [8]. Sustic *et al*.[19] have emphasized adding a brief ultrasound examination to clinical assessment to increase the ability to confirm the placement of DLT. In our study, significantly higher success rate of identification of lung isolation was achieved at first attempt in ultrasound group than in the clinical group (p=0.0028). The average time required to achieve lung isolation was considerably lesser in the ultrasound (192 sec) technique than in clinical methods (250 sec).

The adequacy of lung isolation does not rule out the advancement of the bronchial lumen beyond the secondary carina. Such advancement would result in poor oxygenation, increased airway pressure, or both [8]. So, in addition to functional lung isolation by ultrasound, if the patient's airway pressure and oxygenation status are within normal limits during OLV, then one can safely comment that the DLT position is satisfactory. Brodsky *et al*. described that if DLT is in the correct bronchus with effective lung isolation, and there is no deoxygenation due to malposition, the position of DLT is commented as 'satisfactory,' and FOB need not be a routine part of DLT placement [7].

In our study, though the difference in the mean peak airway pressure between the two groups showed statistical significance, clinical relevance was not seen. However, the result interpretation showed the superiority of the ultrasound group compared to the clinical group with regards to FiO_2 requirement and frequency of patients who desaturated.

Alvarez-Diaz *et al*. showed that 84.5% sensitivity and 41.1% specificity of the clinical method for accurate placement of DLT in a study on 105 patients [20]. In contrast, ultrasound had a much higher sensitivity of 98.6% and specificity of 52.9%. Saporito *et al*. found that thoracic ultrasound done by a trained nurse anesthetist can be as specific and sensitive as FOB in confirming DLT position [21]. Lung USG was more rapid and cost-effective than FOB in confirming LDLT placement. Therefore, it can be suggested that though FOB is a standard gold method in determining precise DLT placement, LUS can be used as a better complementary method to FOB than auscultation in terms of its ability to confirm functional lung isolation [6,13]. In our study, compared to a clinical method, ultrasonography lung had higher sensitivity and specificity for accurate placement of DLT. Further, surgeon satisfaction score was excellent in 26 (76.5%) Group C, 12 (35.3%) patients have excellent score and in Group U, patients have excellent score (p=0.0028).

Due to undersized or oversized tubes, multiple attempts, and inadequate lubrication, several complications, such as sore throat and airway trauma, can occur. We observed a lesser incidence of sore throat in USG group, though it did not achieve statistical significance. This may be attributed to the selection of the appropriate size.

Strengths and limitations of the study

This is a prospective study in which we have independently assessed the accuracy of two techniques. We have focused more on the adequacy of functional isolation of the lungs through airway pressure and FiO_2 requirement, which is critical in thoracic surgery. The final assessment of the placement of DLT was done through direct visualization by surgeon satisfaction score, which was not much used previously.

Our study has many limitations. First, consecutive patients were selected and group allocation was based on the opinion of the consultant anesthesiologist. Randomization was not done. Second, Ultrasonography is also a skill-based technique with the possibility of inter-individual variation during interpretation. Third, lung USG may be unreliable when precise positioning of DLT is mandatory, like broncho-alveolar lavage or massive hemoptysis. In conditions such as surgical pleurodesis or post-inflammatory pleural adhesions, mesothelioma, the lung sliding sign will be absent. It will also be absent during exacerbation of COPD, due to hyperinflation of the lung [13] .Therefore, such conditions must be taken into account before using LUS.

The prediction of DLT size by measuring tracheal diameter through USG has significantly improved the selection of appropriate DLT size. Using lung USG alone or in conjunction with clinical methods also improves the accuracy of confirming functional lung isolation. Further randomized studies are warranted to confirm the findings of our study.

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Table 1. Choice of double-lumen endobronchial tube according to tracheal width.

Measured tracheal width (mm)	Predicted DLT size (Fr)
>18	41
>16	39
>15	37
<14	35

DLT, double lumen tube.

Table 2. Demographic characteristics in both groups.

Parameter	**Group C**	**Group U**	**p-value**
Age (years)	32.77 ± 14.25	34.77 ± 14.36	0.566*
Gender (M/F)	22/12	25/9	0.431#
Height (female)°			
<160 cm	9 (75)	5 (55.6)	0.397
>160 cm	0	1 (11.1)	0.429
<152 cm	3 (25)	3 (33.3)	1.00
Height (male)°			
<170 cm	17 (77.3)	17 (68)	0.530
>170 cm	0	0	1.00
<160 cm	5 (22.7)	8 (32)	0.530

Data expressed as mean ± SD; n (%); *unpaired *t*-test; #Pearson chi-square test; °Fisher's exact test; p-value <0.05 is significant.

Table 3. Difference in DLT size in both the groups.

Actual DLT used	Group 1		Group 2		Z test
	n	%	n	%	
Same as predicted	15	44.0	23	67.6	Z value = -2.01, p=0.044
Higher that predicted	8	23.5	5	14.7	
Lower than predicted	11	32.5	6	17.6	
Total	34	100.0	34	100.0	

DLT, double lumen tube-

Table 4. Sensitivity, specificity and predictive value of clinical and ultrasound to predict size and accuracy of placement of double-lumen tube.

Parameter	Group C			Group U		
	Value (%)	CI-lower limit (%)	CI-upper limit (%)	Value(%)	CI-lower limit (%)	CI-upper limit (%)
Sensitivity	52.17	30.59	73.18	86.67	69.28	96.24
Specificity	18.18	2.28	51.78	25	0.63	80.59
PPV	57.14	45.20	68.31	89.66	82.87	93.95
NPV	15.38	4.61	40.60	20	3.51	63.20
Accuracy	41.18	24.65	59.30	79.41	62.10	91.30

CI, confidence interval; PPV, positive predictive value; NPV, negative predictive value-

Table 5. Parameters assessed for adequacy of lung isolation, surgeon satisfaction score, time required for DLT placement and complications of DLT placement.

Parameter	Group 1	Group 2	p-value*	p-value
Lung isolation				
Lung isolation achieved at first attempt	21 (61.8)	29 (85.3)	0.028	
Peak pressure	16.21 ± 0.98	15.00 ± 0.82		0.0001$^{\#}$
Oxygenation status Saturation (less than 92%)	3 (8.8)	0	0.239	
FiO_2 (more than 0.5) to maintain saturation 92%	16 (47.1)	10 (29.4)	0.212	
Surgeon satisfaction score				
Poor	2 (5.9)	1 (2.9)		0.0028°
Acceptable	20 (58.8)	7 (20.6)		
Excellent	12 (35.3)	26 (76.8)		
Time required for confirmation of position of DLT from intubation				
0-4 minutes	12 (35.3)	31 (91.2)	<0.0001	
4.1-8 minutes	22 (64.7)	3 (8.8)		
Complications				
Sore throat	7 (20.6)	4(11.8)		0.512§
Trauma during intubation	0	0		1.0§
More than one intubation attempt	13 (38.2)	5 (14.7)		0.028§

Data expressed as mean ± SD, n (%). FiO_2, fractional inspired oxygen concentration; DLT, double lumen tube; *Fisher's exact test; $^{\#}$unpaired *t*-test; ° Pearson Chi-square test; §Chi-square test.

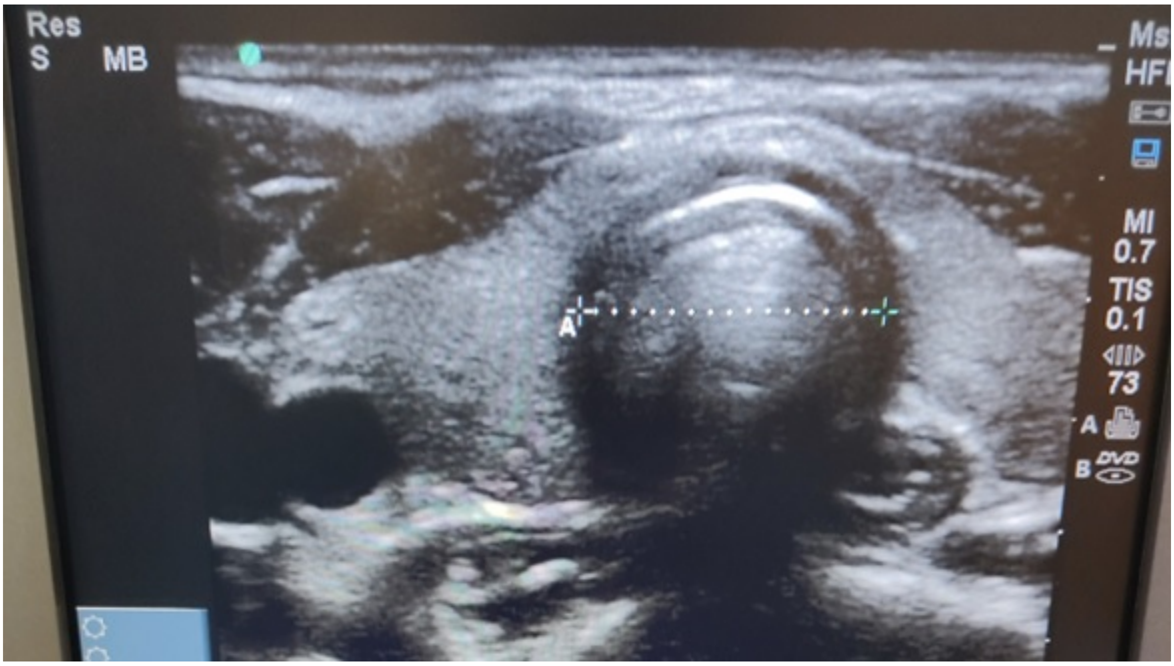

Figure 1. Sonographic image of tracheal diameter measurement at the level of cricoid cartilage.

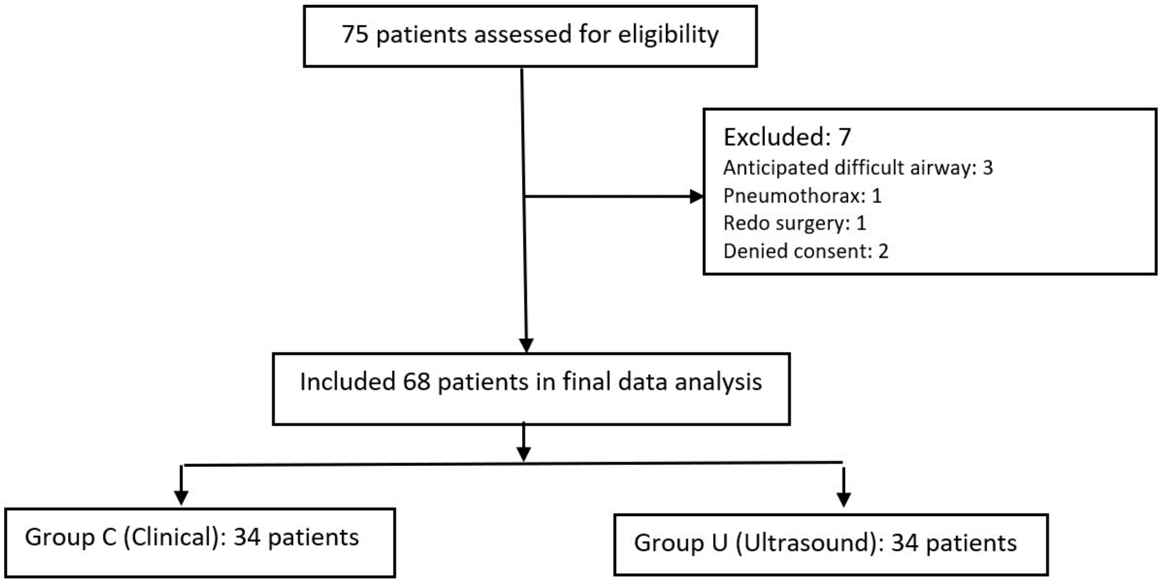

Figure 2. Diagram depicting flow of patients.

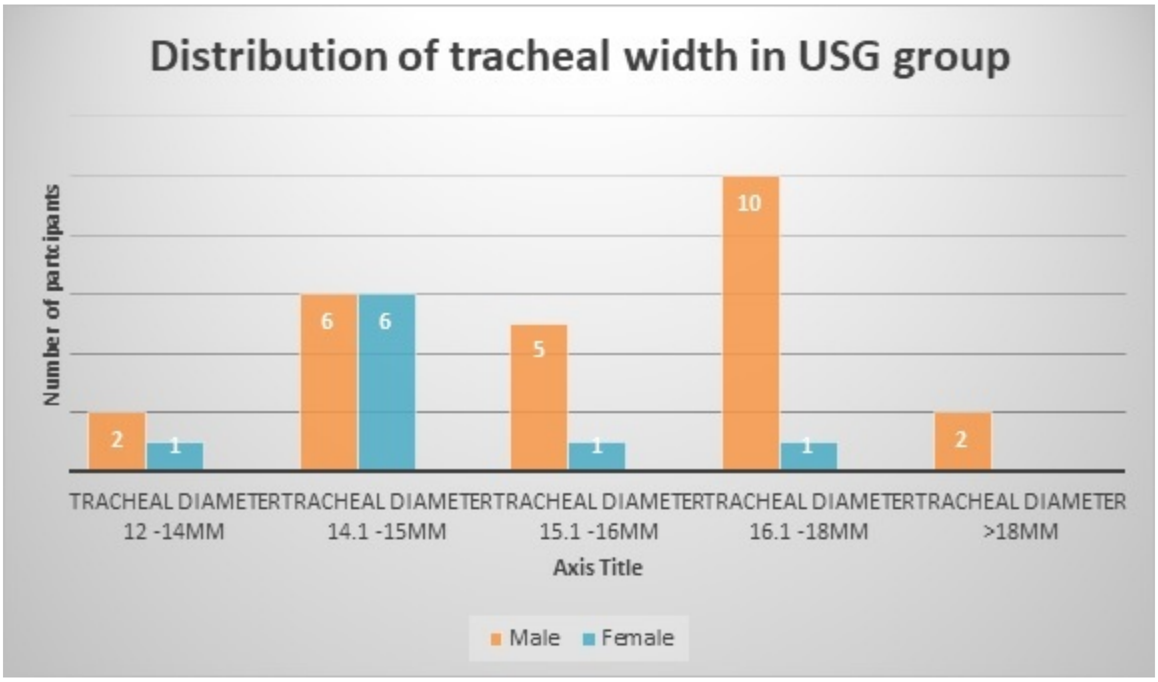

Figure 3. Distribution of tracheal width in ultrasound group.