Preoperative Ultrasonographic Evaluation of Neck Anatomy for Tracheostomy in Adult Patients

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Abstract

Background: Tracheostomy is a surgical procedure that involves creating an opening in the anterior tracheal wall to establish a permanent stoma for respiration. Indications for tracheostomy include prolonged mechanical ventilation, pulmonary toilet, surgical access, and airway obstruction. Ultrasound is increasingly used preoperatively due to its wide availability, noninvasive nature, mobility, affordability, and ease of use.

Objective: To evaluate the anatomy of the tracheostomy surgical site, including subcutaneous tissue thickness, thyroid isthmus thickness, and tracheal ring width, and to assess the correlation among these factors, operative time, and intraoperative blood loss.

Materials and Methods: This study was a prospective descriptive design involved 48 patients undergoing tracheostomy. Clinical histories and physical examinations were conducted, indications for tracheostomy documented, and data on operative time and intraoperative blood loss collected. Preoperative ultrasonography was performed in the operating room, followed by the surgical procedure.

Results: Among 48 patients (56.3% male and 43.8% female), the most prevalent comorbidities were hypertension (70.8%), dyslipidemia (50.0%), diabetes mellitus (35.4%), chronic kidney disease (22.9%), and prior cerebrovascular disease (16.7%). The primary indication for tracheostomy was prolonged mechanical ventilation (85.4%). Ultrasound findings revealed an average subcutaneous tissue thickness of 0.54 cm, an average thyroid isthmus thickness of 0.32 cm, and an average tracheal ring width of 2.20 cm. The average operative time was 37.62 minutes, and the average intraoperative blood loss was 14.68 mL. There were no serious post-operative complications.

Conclusion: Using preoperative ultrasound to evaluate neck anatomy is appropriate for patients who struggle to find comfortable positions during surgery. Additionally, increased subcutaneous tissue thickness and thyroid isthmus may extend the operative time.

Keywords: Tracheostomy; Ultrasound; Preoperative assessment; Subcutaneous tissue; Thyroid isthmus; Tracheal ring width

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Tracheostomy is a procedure that involves creating an opening in the anterior wall of the trachea, providing an airway bypass at the neck[1]. The technique is indicated for prolonged intubation due to airway diseases or neuromuscular conditions (such as myopathy or myelopathy), unconsciousness, an unsecured airway, assistance in clearing secretions, or upper airway obstruction (for instance, bilateral vocal fold paralysis). It has been especially indicated in cases of head and neck tumors or craniofacial defects[1,2].

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What is already known about this topic?

Many studies have examined the benefits of preoperative ultrasound for percutaneous PDT, which can minimize unexpected complications following the procedure. However, this PDT technique has certain contraindications, including patients with thick soft tissue at the anterior neck, an uncertain palpable tracheal ring, and the presence of anterior neck masses. Consequently, the conventional tracheostomy procedure often plays a vital role in problematic cases. Furthermore, otolaryngologists who utilize ultrasound to evaluate neck anatomy would gain advantages from previous studies and perform the procedure without unpredictable complications.

What does this study add?

This study employed a prospective descriptive design to evaluate the anatomy of the tracheostomy surgical site, including subcutaneous tissue thickness, thyroid isthmus thickness, and tracheal ring width. It also aimed to assess the correlation among these factors, operative time, and intraoperative blood loss. The results indicated that preoperative ultrasonography effectively evaluates subcutaneous tissue thickness, thyroid isthmus thickness, and tracheal ring width. Higher values of these parameters, as measured by ultrasound, may correlate with longer operative times. Ultimately, our study revealed no complications following surgery.

Tracheostomy is one of the most common procedures in the ENT Department at Phramongkutklao Hospital. According to reports, 150 tracheostomies were performed in 2019 and 124 in 2020. The timing of the procedure and the occurrence of intraoperative and postoperative complications vary. Anatomical structures, including subcutaneous tissue, the thyroid gland, major vessels, and the trachea, can affect both the duration of the operation and the likelihood of complications[2-4]. Ultrasound is widely used due to its ease of use, portability, affordability, and noninvasive nature. It aids in estimating anatomical structures and helps plan the neck incision for this procedure[5-8].

Objective

The study aimed to: 1) Evaluate the anatomical structures of the anterior neck using ultrasound imaging to enhance the safety and precision of tracheostomy procedures. 2) Evaluate the variability of anatomical landmarks, the connections between critical structures, e.g., the thyroid gland, trachea, blood vessels, and their impact on operative time and blood loss during tracheostomy placement.

Materials and Methods

Study Design

The research employed a prospective descriptive design.

Research Operation

All procedures involving human participants in the studies were conducted according to the ethical standards of the institutional and/or national research committee, the 1964 Helsinki Declaration and its later amendments, or comparable ethical guidelines. Participants included patients with obstructive respiratory conditions requiring ventilatory support and meeting the criteria for tracheostomy surgery.

Population

Inclusion criteria:

1) Patients requiring prolonged intubation due to pulmonary disease, neuromuscular disorders, or myelopathies.

2) Patients requiring pulmonary toilet.

3) Patients requiring a prophylactic airway, such as those with head and neck tumors.

4) Patients with upper airway obstruction, such as bilateral vocal fold paralysis.

Exclusion criteria:

1) Patients needing a tracheostomy due to emergencies.

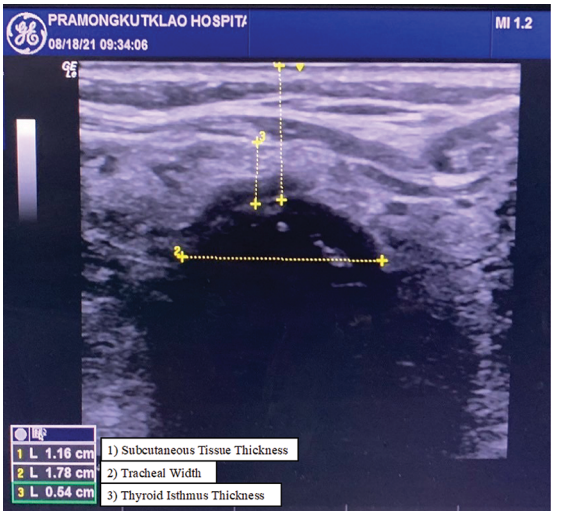

Figure 1. Measurement of the anterior neck soft tissue: 1) subcutaneous tissue thickness, 2) tracheal width, and 3) thyroid isthmus thickness.

2) Tumors obscuring the incisional site at the neck.

3) Patients under 20 years of age.

4) Patients or their relatives refusing to participate in the study.

Methods

1) Patient selection: Patients requiring tracheostomy, meeting the inclusion criteria and providing informed consent, were enrolled in the study.

2) Baseline data recording: Patient details were recorded, such as age, underlying conditions, and coagulation profile.

3) Preoperative neck ultrasound: A neck ultrasound was conducted for all patients before the tracheostomy procedure.

4) Surgical data recording: Details of the procedure, such as incisional design, operative time, and intraoperative blood loss, were recorded.

Neck Ultrasound Procedure

A neck ultrasound was conducted using the GE LOGIQ E10 Ultrasound System. The examiner placed a suitably sized probe horizontally on the patient's neck, beginning at the hyoid bone, across the larynx, and extending down to the sternal notch.

The following data were recorded (Figure 1).

1) Subcutaneous tissue thickness was measured in centimeters.

2) Thyroid isthmus thickness was measured at the pretracheal site of the intended incision in centimeters.

3) Tracheal anatomy was used to identify the

location of the second and third tracheal rings, and tracheal ring width was measured in centimeters.

4) Screening for abnormalities was evaluated for other irregularities, such as the presence of major vessels or neck masses.

Tracheostomy Procedure

After intubation and anesthesia induction, all patients were positioned supinely with the neck extended to optimize surgical access. Vital signs, including heart rate, blood pressure, and oxygen saturation, were continuously monitored throughout the procedure. The tracheostomy incision site was determined based on anatomical landmarks, marked either one finger breadth below the cricoid cartilage or two finger breadths above the sternal notch. Local anesthesia was administered subcutaneously using 1% xylocaine at the incision site. Depending on the clinical situation, the incision was made as a horizontal or vertical line. Once the skin was incised, the strap muscles were separated along the midline (white line) and retracted to expose the thyroid isthmus. The isthmus was then handled by retracting it either superiorly or inferiorly, or by dividing it, when necessary, to provide access to the anterior tracheal wall. After approaching the anterior tracheal wall, a stay suture was placed, and an inverted U-shaped flap was created to insert the tracheostomy tube[1,2].

Statistical Analysis

The data were recorded in a file format using Stata Statistical Software, version 17 (StataCorp LLC, College Station, TX, USA) and were analyzed statistically, including the techniques listed below.

1) Descriptive statistics included count, percentage, mean, standard deviation, minimum value, and maximum value for general information.

2) Pearson's correlation was employed to analyze the relationship between variables.

3) An independent samples t-test was used to compare the means of two independent groups.

4) Logistic regression: analyzed the relationship between two independent variables.

5) Statistically significant results were indicated with a p-value less than 0.05.

Results

This study included 48 participants indicated for tracheostomy. The general characteristics of the participants are summarized in Table 1. Of the 48 participants, 27 were male (56.3%) and 21 female (43.8%). The most common comorbidities were hypertension among 34 participants (70.8%), hyperlipidemia among 24 participants (50%), diabetes among 17 participants (35.4%), chronic kidney failure among 14 participants (29.2%), stroke among 8 participants (16.7%), and other diseases.

Table 1. Participants' demographic data (n=48)

Variables	n (%)
Sex	
Male	27 (56.3)
Female	21 (43.8)
Hypertension	34 (70.8)
Dyslipidemia	24 (50.0)
Diabetes mellitus	17 (35.4)
Chronic kidney disease	14 (29.2)
Cerebrovascular disease	8 (16.7)
Indications	
Prolonged intubation	41 (85.4)
Airway protection	6 (12.5)
Pulmonary toilet	1 (2.1)
Incision	
Horizontal	25 (52.1)
Vertical	23 (47.9)

Table 2. Relationship analysis variables

Variables	Mean±SD
Subcutaneous tissue (cm)	0.54±0.20
Thyroid isthmus (cm)	0.32±0.21
Tracheal ring width (cm)	2.20±0.39
Operative time (minutes)	37.62±19.46
Blood loss (mL)	14.68±11.68
Prothrombin time (minutes)	13.64±1.89
International normalized ratio	1.18±0.16

SD=standard deviation

For 41 participants (85.4%), the primary reason for surgery was prolonged intubation lasting more than 14 days. This was followed by surgery for airway protection among 6 participants (12.5%) and the inability to expel secretions independently in 1 participant (2.1%). The surgical incision was made horizontally for 25 participants (52.1%) and vertically for 23 participants (47.9%).

Table 2 shows that the average age of the participants is 75.63±16.49 years. The average blood coagulation values, prothrombin time (PT), and international normalized ratio (INR) were 13.64±1.89 and 1.18±0.16, respectively.

The ultrasound examination of the anatomical structures in front of the trachea revealed the following averages: the thickness of the subcutaneous tissue

Table 3. Relationship between the values measured by ultrasound, the duration of surgery, and the amount of blood loss

Ultrasound measurements	Operative time (minutes)	Blood loss (mL)
Subcutaneous tissue (cm)		
r	0.005	−0.049
p-value	0.973	0.742
Thyroid isthmus (cm)		
r	0.202	−0.086
p-value	0.170	0.566
Tracheal ring width (cm)		
r	0.091	0.074
p-value	0.540	0.623

Pearson's correlation

was 0.54±0.2 cm, the thickness of the thyroid isthmus was 0.32±0.21 cm, and the width of the tracheal ring measured 2.20±0.39 cm. As shown in Table 2, the average surgical time was 37.62±19.46 minutes, and the average blood loss was 14.68±11.68 milliliters.

The study found no complications, including airway burns, pulmonary air leaks, and incorrect intubation during and after surgery.

The ultrasound measurements indicated that a greater thickness of the subcutaneous tissue in front of the trachea was associated with a longer operative time but reduced blood loss. Increased thickness of the thyroid isthmus tended to increase operative time, while resulting in lower blood loss. A wider trachea, on the other hand, correlated with prolonged surgical duration and increased blood loss. However, no statistically significant relationships were identified between these measurements and surgery duration or blood loss (Table 3).

The findings indicated a statistically significant relationship between participants with dyslipidemia and the thickness of the thyroid isthmus (p=0.009). Other factors, including sex and additional comorbidities, did not show a statistically significant relationship with the ultrasound measurements, such as subcutaneous tissue thickness, thyroid isthmus thickness, and tracheal ring width (Table 4).

The study showed that a subcutaneous tissue thickness greater than 0.7 cm was associated with an operative time exceeding 30 minutes (OR 1.571, p=0.693). Additionally, increased subcutaneous tissue thickness and thyroid isthmus contributed to an operative time exceeding 30 minutes (OR 2.920, p=0.486 and OR 12.789, p=0.09), as indicated in Table 5.

The data in Table 6 demonstrate that thicker subcutaneous tissue and thyroid isthmus were associated with blood loss of less than 10 ml; however, this relationship was not statistically significant.

Table 4. Relationship among comorbidities and values measured by ultrasound

	Subcutaneous tissue (cm) Mean±SD	p-value	Thyroid isthmus (cm) Mean±SD	p-value	Tracheal ring width (cm) Mean±SD	p-value
Sex		0.727		0.303		0.901
Male	0.544±0.22		0.287±0.201		2.211±0.417	
Female	0.524±0.167		0.352±0.231		2.196±0.373	
HT		0.82		0.277		0.691
No	0.525±0.194		0.263±0.184		2.169±0.381	
Yes	0.539±0.201		0.338±0.225		2.219±0.405	
DLP		0.812		0.009*		0.396
No	0.528±0.161		0.237±0.18		2.155±0.398	
Yes	0.542±0.231		0.395±0.221		2.253±0.394	
DM		0.595		0.185		0.331
No	0.524±0.163		0.346±0.197		2.163±0.365	
Yes	0.556±0.251		0.26±0.239		2.28±0.445	
CKD		0.432		0.598		0.193
No	0.55±0.216		0.326±0.218		2.156±0.393	
Yes	0.5±0.14		0.29±0.212		2.321±0.387	
CVA		0.754		0.92		0.558
No	0.539±0.206		0.317±0.194		2.22±0.411	
Yes	0.515±0.147		0.309±0.314		2.129±0.314	

SD=standard deviation; HT=hypertension; DLP=dyslipidemia; DM=diabetes mellitus; CKD=chronic kidney disease; CVA=cerebrovascular disease
Independent sample t-test

Table 5. Relationship among ultrasound measurements and operative time

Operative time	≤30 minutes	>30 minutes	p-value	Crude odds ratio	95% CI
Subcutaneous tissue (cm); mean±SD	0.52±0.16	0.55±0.23	0.486	2.920	0.14 to 59.69
Thyroid isthmus (cm); mean±SD	0.26±0.18	0.37±0.23	0.09	12.789	0.67 to 243.16
Subcutaneous tissue; n (%)					
≤0.7 cm	22 (51.2)	21 (48.8)		1	
>0.7 cm	2 (40.0)	3 (60.0)	0.639	1.571	0.24 to 10.37

CI=confidence interval; SD=standard deviation
Logistic regression

Table 6. Relationship between ultrasound measurements and blood loss during surgery

Blood loss	≤10 mL	>10 mL	p-value	Crude odds ratio	95% CI
Subcutaneous tissue (cm); mean±SD	0.54±0.23	0.54±0.13	0.979	0.959	0.043 to 21.568
Thyroid isthmus (cm); mean±SD	0.34±0.22	0.27±0.2	0.276	0.196	0.011 to 3.668
Subcutaneous tissue; n (%)					
≤0.7 cm	27 (64.3)	15 (35.7)		1	
>0.7 cm	4 (80.0)	1 (20.0)	0.493	0.45	0.046 to 4.401

CI=confidence interval; SD=standard deviation
Logistic regression

Discussion

When comparing the results of this study to those of related research, the average thickness of the subcutaneous tissue and the tracheal diameter were in similar ranges: 0.55, 1.01, and 2.22 cm and 2.10 cm, respectively[3]. However, the average surgery time varied, averaging 38 minutes in this study compared with 10 minutes in the research by Guinot et al[3]. Furthermore, Yavuz et al.[4] found that patients receiving an ultrasound before tracheostomy experienced a shorter average surgery time and fewer complications compared with those who did not. Both studies suggest that ultrasound helps provide more precise anatomical positioning, leading to more successful surgeries, fewer complications, and improved safety for patients undergoing tracheostomy.

In our hospital, the tracheostomy procedure is typically performed using the conventional technique, usually conducted by otolaryngologists. In certain cases, pulmonologists in the intensive care unit (ICU) may carry out percutaneous dilatational tracheostomy (PDT). This PDT technique is suitable for patients who present with thin soft tissue at the anterior neck, a clearly palpable tracheal ring, and an absence of anterior neck masses[4,6]. Consequently, the patients enrolled in our study were not eligible for PDT and were challenging to operate on. The study also found that most participants were elderly patients admitted to critical care units. The narrow age range of the sample limited the ability to investigate the relationship between age and ultrasound-measured outcomes. The patients' blood coagulation values generally fell within normal limits (INR ≤1.2). The ultrasound procedures were performed by multiple physicians, which could contribute to some inconsistencies. The tracheostomy was carried out by physicians with varying levels of experience, including residents and attending physicians. Furthermore, with only 48 participants, the limited sample size may have influenced data distribution and analysis. A larger sample size could have affected the results, potentially altering the relationships among various factors and ultrasound measurements, which may impact surgery time and blood loss.

According to a study conducted by Guinot et al.[3], our results indicated that the increased thickness of the subcutaneous tissue and thyroid isthmus may require surgeons to exercise greater caution during surgery, especially when considering anatomical structures and potential intraoperative complications. This could result in longer surgery times; however, no complications were observed during the surgeries in this study.

Using ultrasound to evaluate anatomical structures prior to tracheostomy offers distinct advantages compared to relying solely on physical examination. It allows for precise measurements of subcutaneous tissue and thyroid isthmus thickness, enhancing visualization of the trachea, especially in cases where it cannot be palpated or is deviated. These benefits

enable physicians to better estimate surgery duration and exercise increased caution during the procedure. Furthermore, data obtained from preoperative ultrasonography can assist in planning the surgical incision[8]. This research establishes a foundation for future studies that could compare surgery times and blood loss between patients undergoing preoperative ultrasound prior to tracheostomy and those who do not. In addition, the results indicate that the thickness of the thyroid isthmus is significantly related to patients with dyslipidemia, as a recent study by Zhang et al.[9] demonstrated the association between patients with thyroid nodules and metabolic disorders. These associated findings are interesting and warrant further investigation to clarify this relationship.

Conclusion

The use of ultrasound to examine the anatomical structures in the neck before performing a tracheostomy is beneficial and complements the physical examination. Preoperative ultrasound of the neck is suitable for patients who have difficulty finding comfortable positions during surgery. Additionally, increased subcutaneous tissue thickness and thyroid isthmus may extend the duration of the surgery.

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Author Contributions

PK: Conceptualization, methodology, writing-original draft, project administration, supervision (principal investigator), funding acquisition. JC: Investigation, data curation, validation (co-investigator). KL: Investigation, resources, validation (co-investigator). SR: Supervision, methodology, formal analysis. MA: Investigation, resources (co-investigator). EC: Investigation, resources (co-investigator). PW: Supervision, investigation, writing-review & editing (advisor).

Clinical Trial Registration

Additionally, this study was registered with the Thai Clinical Trials Registry (TCTR) on February 2, 2026, under TCTR20260202020. The registration occurred after the research project was completed because the authors submitted a request to the IRB to reduce the number of participants below the calculated sample size.

Conflicts of Interest

The authors declare no conflict of interest.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author (PK) upon reasonable request, pending institutional ethical approval and data-sharing agreements at Phramongkutklao Hospital.

Ethics Approval and Consent to Participate

The study was performed at Phramongkutklao Hospital on March 14, 2022, with approval from the Institutional Review Board of the Royal Thai Army Medical Department (Research Identification Number: IRBRTA 332/2565). Informed consent was obtained from all participants' relatives.

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Use of Artificial Intelligence

During the preparation of this work, the authors used Gemini in order to assist with the structural organization and formatting of the manuscript metadata (such as authors' contributions and data availability statement). Additionally, the authors utilized Grammarly to improve English grammar and readability. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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