ORIGINAL ARTICLE

The accurate identification of the percutaneous tracheostomy insertion site using digital palpation in children

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ABSTRACT

BACKGROUND: Percutaneous tracheostomy (PT) may be required frequently in long-term ventilated intensive care patients. Although the overall risks are low, serious complications may occur, especially in children. Hence, this study aimed to assess physician accuracy in identifying PT insertion sites by digital palpation in children aged between 5 and 13 years.

METHODS: Participants were asked to identify the needle entry point (interspace between 2nd and 3rd or 3rd and 4th tracheal rings) for PT using digital palpation. Then, a single operator scanned the neck of each child with a linear high-frequency transducer. An accurate estimation was defined as a mark made between the upper and lower borders of the tracheal rings within the midline.

RESULTS: In the study including 104 patients, the PT insertion site was accurately identified with digital palpation in a total of 50.9% of patients, compared with sonographic findings. The time required to determine the PT entry point by USG was longer than the palpation technique (114.7 vs. 43.8 s, P<0.001). The mean distance between the entry points of both methods was 4.53±2.03 mm. The majority of inaccurate assessments (45%) was above the 2nd tracheal ring. The lower the skin-to-air-mucosal interface distance, the higher the success of the PT entry point detection with the digital palpation method. A one-unit increase in body mass index was related to increasing the risk of failure by 1.1 times (P=0.030).

CONCLUSION: Significant physician inaccuracy exists in PT insertion sites in children aged between 5 and 13 years, especially as BMI increases. Pre-procedural USG may help identify the landmarks for PT.

Keywords: Child; percutaneous tracheostomy; ultrasonography.

INTRODUCTION

Tracheostomy is a commonly performed procedure in pediatric intensive care units to establish a secure airway for long-term ventilation and management of critically-ill children.[1-3] Percutaneous tracheostomy (PT) refers to creating a stoma in the anterior wall of the trachea with the use of a combination of dilators and PT tubes. The traditional approach of PT is based on anatomical landmarks, such as the cricoid cartilage and tracheal rings, to guide the entry point of the PT tube. While widely accepted and relatively straightforward, this technique carries certain risks and complications.[4] These risks and complications can include damage to nearby structures including the thyroid gland, accidental decannulation, or pneumothorax.[5,6] In the lower part of the airway, the damage to nearby vascular structures comes to the forefront, whereas if the upper parts are selected, subglottic stenosis may occur, so the determination of the appropriate entry point (between the 2nd and 3rd tracheal rings [T2-T3] or between the 3rd and 4th tracheal rings [T3-T4]) may be the most important step

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of the procedure.[7] Thus, the practitioner must be able to identify the appropriate insertion point between the tracheal rings accurately. It has been shown that ultrasound (USG) imaging can help identify optimal puncture sites and assess the distance to important structures, such as the thyroid gland in adults.[8] On the other hand, airway management is particularly challenging in the pediatric population due to the smaller and less prominent anatomical structures and soft cartilage.[6]

In recent years, many studies have been published about the identification of the cricothyroid membrane (CTM) in children.[9,10] However, there remains a paucity of data regarding the identification of the tracheostomy insertion site, although it is used much more frequently.

Therefore, the present study aimed to determine the accurate identification of tracheostomy insertion sites using digital palpation, compared with USG in pediatric patients.

MATERIALS AND METHODS

Study Design and Population

The present study was conducted on pediatric patients aged between 5 and 13 years undergoing anesthesia and surgery for any reason, except for airway surgery. After the approval obtained from the ethics committee and the ClinicalTrials.gov registration (NCT05834972), a total of 105 pediatric patients for whom verbal and written parental consent was obtained were included in the study. In terms of the exclusion criteria, children with the American Society of Anesthesiology criterion of ≥3, abnormal anatomy of the neck or global developmental delay, previous neck surgery, or tracheostomy were excluded from the study.

During the procedure, the patients were positioned in the supine position on the operating table with the neck extended. The head was placed in a neutral position or slightly extended to facilitate access to the trachea and enhance the visualization of anatomical landmarks. Furthermore, a shoulder roll was used to hyperextend the neck slightly and improve the alignment of the airway.

Data Collection

Four physicians (two anesthesiologists and two pediatricians) with at least 5 years of experience were asked to identify the needle entry point (interspace between 2nd and 3rd or 3rd and /4th tracheal rings) for tracheostomy with an ultraviolet invisible pen using the digital palpation on separate patients, respectively.[11] The physicians were asked to report which of these two ranges they chose, and their answers were recorded. Then, a single operator (EG) with expertise in upper airway USG scanned the neck of each child with a linear high-frequency transducer (10–18 MHz), as described previously.[12,13] Thyroid cartilage, cricoid cartilage, tracheal rings, and suprasternal notch were identified through USG, and the tissue-air boundary was visualized. Again, the appropriate entry site for tracheostomy was determined by sliding a needle (used only as a marker) underneath the transducer from the cranial end until it casts a shadow (red line) at the edges of tracheal rings up to the 4th ring and marked on the skin (Fig. 1). An accurate estimation was defined as a mark made between the upper and lower borders of the tracheal rings within the midline. The distances between estimated and determined points and skin-to-air-mucosal interface were also measured. The primary outcome was the accuracy of digital palpation to identify the entry point of the tracheostomy device, compared with ultrasonographic control. The secondary outcomes were as follows: (1) Anatomical identification of the points marked by the participants, (2) The time required to determine the entry point for tracheostomy for both methods, and (3) Demographic characteristics of the patients leading to misidentification of CTM.

In the continuation of the procedure, the marks on the neck were erased, the roles below the shoulder were removed, and the participants were handed over to the surgeon.

Statistical Analysis

Mean ± standard deviation (SD) and median (25th–75th quartiles) were given as descriptive statistics for the variables; the differences in proportions between the groups were compared by using the McNemar test, where appropriate, and the

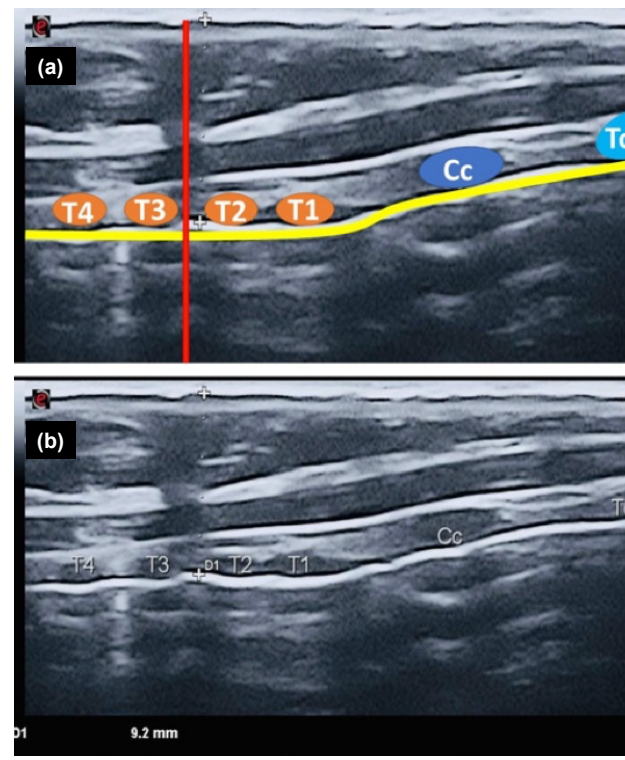

Figure 1. (a) Schematic demonstration and **(b)** ultrasound image of airway anatomy in midline sagittal plane. Yellow line: The air-mucosal interface, Red line: The shadow of the needle sliding underneath the transducer to mark the space between the 2nd and 3rd tracheal rings. Cc: Cricoid cartilage, Tc: Thyroid cartilage, T1: The 1st tracheal ring, T2: The 2nd tracheal ring, T3: The 3rd tracheal ring, T4: The 4th tracheal ring.

Table 1. Patients' characteristics

	Mean±SD	Median (25th-75th)
Age	7.91±2.51	8 (6-10)
Weight (kg)	31.27±15.68	26 (20-36)
Height (m)	1.28±0.16	1.28 (1.15-1.37)
BMI (kg/m^2)	18.18±4.68	16.64 (15.12-19.75)
Sternomental distance (mm)	12.67±2	13 (11.5-14)
Thyromental distance (mm)	7.27±1.38	7.5 (6.5-8)
Neck circumference (cm)	29.28±3.84	29 (26-31)

BMI: Body mass index; SD: Standard deviation.

results were summarized using row-column percentages with frequency distributions. The receiver operating characteristic curves were used to describe and compare the performance of the diagnostic value of USG and the digital palpation technique. The area under the corresponding curves (AUC) was calculated and compared as described by the Hanley and McNeil method.[14] AUCs were summarized with their standard errors and 95% confidence intervals and are presented visually as a figure. For the variables whose diagnostic powers were found to be statistically significant, the cut-off points determined under the Youden's index are given together with the relevant sensitivity and selectivity points to define the independent risk factors of outcome variables. In addition, the risk factors affecting the failure were evaluated by Enter regression method with the univariate logistic model. A P<0.05 was considered as statistically significant. All statistical methods of the study findings were evaluated with the Statistical Package for the Social Sciences software version 26.0 (IBM SPSS Inc., Chicago, IL, USA).[15]

Table 2. Determined entry points for tracheostomy in digital palpation approach.

Determined entry point	Digital Palpation (n, %)
Successful	53 (50.9)
T2-T3	42 (40.4)
T3-T4	11 (10.5)
Unsuccesful	51 (49.1)
C-T1	3 (2.9)
T1	2 (1.9)
T1-T2	18 (17.3)
T2	22 (21.1)
T3	4 (3.8)
T4	2 (1.9)

Cc: Cricoid cartilage; T1: The 1st tracheal ring; T2: The 2nd tracheal ring; T3: The 3rd tracheal ring; T4: The 4th tracheal ring.

RESULTS

A total of 105 subjects were recruited for the present study. One patient was excluded from the study because an adhesion was detected due to a possible variation between the 2nd and 3rd tracheal rings with USG and the data from 104 patients were analyzed. Of 104 patients, 66 were male (63.4%), and 38 were female (36.6%). The mean age of the participants was 7.91±2.51 years, and the mean body mass index (BMI) was 18.18±4.68 kg/m2. While the average sternomental distance of the participants was 12.67±2.00 mm, the thyromental distance and the neck circumference were measured as 7.27±1.38 mm and 29.28±3.84 cm, respectively (Table 1).

The appropriate entry point for PT (T2-T3 or T3-T4) was successfully identified in 53 out of 104 patients with palpation (50.9%) (Table 2). The majority of inaccurate assessments (45%) was above the 2nd tracheal ring. Both physicians' areas of expertise and years of experience were not associated with the accuracy of digital palpation (P>0.05). In the USG-guided approach, the appropriate entry site was successfully identified in all, but not one patient (99.04%). Furthermore, vascular structures were observed in two patients on USG image at the entry point determined through the digital palpation method (1.90%).

The time required to determine the PT entry point by digital

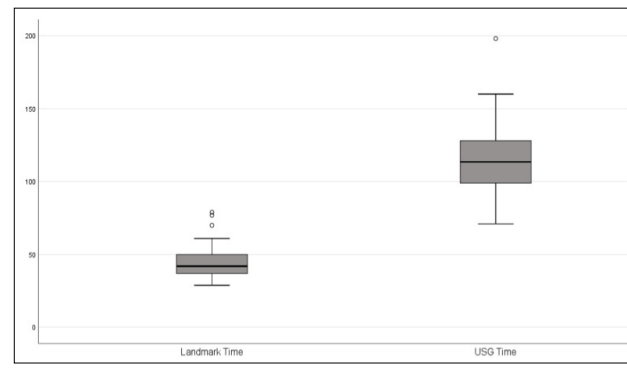

Figure 2. Time taken to identify the entry point using palpation and ultrasonography.

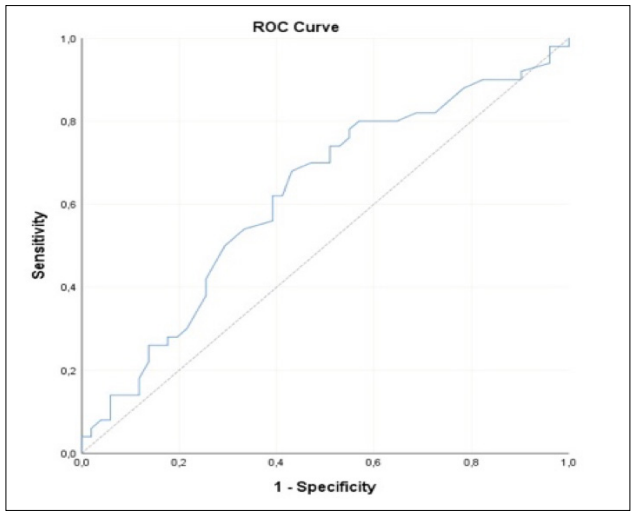

Figure 3. The skin-to-air-mucosal interface distance and success in finding an appropriate entry point.

palpation through USG was longer than the DP technique (P<0.001) (Fig. 2 and Table 3).

The distance between the entry points determined by the palpation and USG-guided approach was measured, and the mean distance between the two entry points was found to be 4.53±2.03 mm; the average skin-to-trachea distance was also measured as 8.77±2.76 mm (Table 3).

The univariate logistic regression of variables that may be associated with accuracy of identifying the tracheostomy insertion site is summarized in Table 4. Accordingly, only the BMI variable had a statistically significant effect on failure. It was observed that a one-unit increase in BMI was related to increasing the risk of failure by 1.1 times (P=0.030).

In addition, the skin-to-air-mucosal interface distance was found to be associated with determining the appropriate entry point for tracheostomy entry. The lower the skin-to-air-mucosal interface distance, the higher the success of the detection of the tracheostomy entry point with the digital palpation method (Fig. 3).

DISCUSSION

The findings of the present study reveal that the accuracy of palpation to detect the tracheostomy site is 50.9%, compared with that of USG findings in children aged between 5 and 13 years. Our findings also suggest that as the skin-air-mucosal interface distance decreases, the success of detecting the entry point with the digital palpation method increases.

In light of the literature, many studies have investigated the determination of CTM in children.[9,10] Tracheostomy is a more frequently performed technique than cricothyroidotomy by clinicians. To the best of our knowledge, the present study is the first to compare the success and accuracy of

Table 3. The time required to determine the entry point, and the distances of importance

	Mean±SD	Median (25th-75th)
Time required to determine entry site (sec)		
DP	43.85±9.67	42(37-50)
USG-guidance	114.79±21.12	113.5(99-128)
Distances (mm)		
DP-USG vertical distance	4.53±2.03	4(2-6)
Skin-to-air-mucosal interface distance	8.77±2.76	8.7(6.3-10.2)

DP: Digital palpation; SD: Standard deviation; USG: Ultrasonography.

Table 4. Univariate analysis using logistic regression method of patient characteristics

	Beta (SE)	OR (95%CI)	P value
Age	0.012±0.07	1.01(0.86-1.18)	0.875
Weight (kg)	0.019±0.01	1.01(0.99-1.04)	0.156
Height (m)	0.110±1.21	1.11(0.10-12.05)	0.927
BMI (kg/m^2)	0.105±0.04	1.11(1.01-1.22)	0.030
Sternomental distance (mm)	-0.070±0.10	0.93(0.76-1.13)	0.486
Thyromental distance (mm)	0.062±0.14	1.06(0.80-1.41)	0.667
Neck circumference (cm)	0.095±0.54	1.09(0.98-1.22)	0.079

SE; Standart Error; OR (95%CI); Odds Ratio and 95% Confidence Intervals.

digital palpation and USG in determining the tracheostomy site in children. In addition, the literature related to the use of USG in PT procedures in children is relatively limited, compared to the adult population.

The ideal location of the tracheostomy is between the 2nd and 3rd or 3rd and 4th tracheal rings.[16] Entering the trachea from upper levels, such as between the T1-T2, has the risk of subglottic stenosis; even so, entering below the T4 has the risk of injury to the great vessels.[17] Among our participants, vascular structures were observed in two (1.90%) patients on the USG image at the insertion area. In other words, if the tracheostomy had been performed through the digital palpation method without USG assistance, potential complications, such as vascular injuries, could have been observed. Therefore, injuries to the vascular structures close to the tracheostomy insertion site can be prevented using real-time USG or changing the entry point.

In the study conducted on critically ill patients by Dugg et al., the success of digital palpation was found to be lower.[16] However, the palpation of landmarks is considerably harder in the pediatric population. Our results are similar to those reported in the aforementioned study in terms of the success of USG guidance in determining PT entry points.

In this study, we also compared the time taken to determine the entry point with two different methods, and the mean time taken to identify the entry point was significantly longer in the USG technique than in the digital palpation. These results are also consistent with those reported in the study by Dugg et al.[18] Since the physician needs to determine both the thyroid and cricoid cartilages, and the space between the T2-T3 or T3-T4 is required to slide a needle, USG takes more time than the palpation. Therefore, the time difference between the two methods was measured as approximately 1 min. Considering the possible complications and the patients for whom the traditional method is insufficient, it is obvious that the one-minute extra time in the USG technique for the determination of the entry point can be ignored.

The skin-to-trachea distance was found to be associated with determining the appropriate entry point for tracheostomy access. The lower distance of the skin-to-trachea is interpreted as a lower BMI of the patient. The palpation of anatomical structures is easier in leaner patients than in the obese. Therefore, it is not surprising that the success of digital palpation increases in patients with a lower skin-to-trachea distance. However, in some studies comparing the determination of the CTM through palpation and ultrasonography methods, no difference was found between obese and non-obese children.[19] This might be related to the skin to CTM distance which is thinner than the pre-tracheal soft-tissue depth.

Airway USG enables the visualization of various anatomical structures, such as the thyroid cartilage, cricoid cartilage, CTM, tracheal rings, and esophagus.[16] In our study, vascular structures were observed in two (1.90%) patients on the USG image at the insertion area. Pre-tracheal vessels are very common in the general population overlying potential PT insertion sites.[20] If the tracheostomy had been performed through the digital palpation method without USG assistance, vascular injuries could have been observed. Injuries to vascular structures close to the tracheostomy insertion site, therefore, can be prevented using real-time USG or changing the entry point.[21] Pre-procedural use of USG for airway assessment may be beneficial in terms of the safety and accuracy of the tracheostomy procedure in pediatric patients. USG-guided tracheostomy may be particularly useful to overcome and minimize the challenges and complications in those with challenging neck anatomy or obese patients.[22]

USG has provided a fundamental change in the management of the airway. With USG of the airway, the tongue, oropharynx, hypopharynx, epiglottis, larynx, vocal cords, cricoid cartilage, trachea, and cervical esophagus can be easily visualized in children.[23] The ultrasonographic evaluation before airway interventions can be a game changer in terms of the safety and effectiveness of the procedure. With increasing evidence and accessibility, USG is likely to be used routinely in the management of the airway.

This study has also several limitations. This is an observational study; the determination of the insertion point of PT was investigated, and no interventional procedures were performed. We consider that further studies are needed to determine the success of digital palpation and USG for PT procedures in children. Then, since the study was carried out in children and a single center, our study findings cannot be generalized to other age groups and other regions.

CONCLUSION

Airway management in pediatric patients is challenging due to their anatomical differences. It is noteworthy how frequently the digital palpation fails us to detect the appropriate entry point for PT. Furthermore, the digital palpation approach may have a limited role in predicting complications. The incorporation of the pre-procedural ultrasonographic assessment to the accurate identification of the PT insertion site should be considered in evaluating children. We consider that further studies with larger populations from different age groups are needed to elucidate the entity in PT procedures.

Ethics Committee Approval: This study was approved by the Aksaray University, Faculty of Medicine Ethics Committee (Date: 16.03.2023, Decision No: 2023/05-05).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: C.K.; Design: C.K., E.G; Supervision: C.K., O.K.; Data collection and/or processing: E.G; Analysis and/or interpretation: C.K., O.K.; Literature search: C.K., E.G., O.K.; Writing: C.K., E.G; Critical review: O.K.

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Çocuklarda dijital palpasyon kullanılarak perkütan trakeostomi yerleştirme bölgesinin tanımlanma doğruluğu

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AMAÇ: Perkütan trakeostomi (PT) uzun süreli ventilasyona bağlı yoğun bakım hastalarında sıklıkla gerekli olabilir.Genel riskler düşük olmakla birlikte, özellikle çocuklarda ciddi komplikasyonlar meydana gelebilir. Bu çalışmada, 5-13 yaş arası çocuklarda PT giriş noktasının dijital palpasyonla belirleme doğruluğunun değerlendirilmesi amaçlandı.

GEREÇ VE YÖNTEM: Katılımcılardan dijital palpasyon kullanarak PT için iğne giriş noktasını (2./3. veya 3./4. trakeal halkalar arasındaki boşluk) belirlemeleri istendi. Daha sonra, tek bir operatör lineer yüksek frekanslı transduser kullanarak trakeal bölgede ilgili anatomik yapıları belirledi. Doğru tahmin, orta hat içinde ilgili trakeal halkaların üst ve alt sınırları arasındaki işaret olarak tanımlandı.

BULGULAR: 104 hastayı kapsayan çalışmada sonografik bulgularla karşılaştırıldığında hastaların toplam %50.9'unda dijital palpasyonla PT giriş yeri doğru olarak saptandı. USG ile PT giriş noktasının belirlenmesi için gereken süre palpasyon tekniğinden daha uzundu (114.7'ye karşı 43.8 saniye, p<0.001). Deriden hava mukoza temas çizgisi arasındaki mesafesi ne kadar düşükse, dijital palpasyon yöntemiyle PT giriş noktası tespitinin başarısı o kadar yüksekti. Her iki yöntem giriş noktaları arasındaki ortalama mesafe 4.53±2.03 mm idi. Hatalı değerlendirmelerin çoğu (%45) 2. trakeal halkanın yukarısındaydı.Vücut kitle indeksindeki bir birimlik artış, başarısızlık riskinin 1.1 kat artmasıyla ilişkiliydi (p=0.030).

SONUÇ: 5-13 yaş arası çocuklarda özellikle VKİ arttıkça PT yerleştirme yerinin belirlenmesinde önemli yanlışlıklar bulunmaktadır. Prosedür öncesi USG, PT için yer işaretlerinin belirlenmesine yardımcı olabilir.

Anahtar sözcükler: Çocuk; perkütan trakeostomi; ultrasonografi.

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