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Comparative effectiveness of real-time ultrasound-guided tracheostomy and anatomic landmark percutaneous dilatational tracheostomy: a retrospective cohort study

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Abstract. – OBJECTIVE: The role of ultrasound during various airway procedures has been in the spotlight in recent years. This study reconsiders the potential role and effectiveness of ultrasound use during percutaneous dilatational tracheostomy in intensive care patient population. This study aims to assess the impact of real-time ultrasound (US) use on complication rates and procedural success in percutaneous dilational tracheostomy (PDT) opened with forceps dilatation technique using anatomical landmarks.

PATIENTS AND METHODS: In this study, 59 patients who had undergone PDT in the intensive care unit (ICU) were reached. Written-electronic files and intensive care follow-up forms of the patients were reviewed retrospectively. The patients were divided into two groups: 44 patients in Group G (anatomical landmark PDT) and 15 patients in Group U (real-time US PDT). Demographic data, duration of intubation and ICU stay, discharge status, procedural characteristics and postoperative complications of the patients were determined.

RESULTS: A total of 59 patients were analyzed. The mean age of the patients was 74.9±11.7 years, the mean tracheostomy duration was 33.3±20 days, and the mean duration of ICU stay was 60±45 days. Complications occurred in 62.7% of all patients. Minor bleeding was present in five (8.5%), moderate bleeding in 13 (22%), and major bleeding in 11 (18.6%) patients. In addition, pneumothorax was observed in one patient, misplacement of the tracheostomy cannula and emphysema in one patient, and esophageal injury in three patients. A total of 50 (84.7%) patients died, and nine (15.3%) patients continued to be treated in the ICU. Bleeding, hypoxemia, hypercapnia, tracheostomy opening time duration, and the number of attempts for the successful procedure were significantly higher in Group G than Group U ($p<0.05$). A negative correlation was found between the groups regarding the duration of tracheostomy ($p = 0.001$) and tracheostomy opening technique ($p = 0.001$).

CONCLUSIONS: The use of real-time ultrasound in percutaneous tracheostomies opened under elective conditions in the ICU reduces the complications of hypoxemia, hypercapnia and bleeding by dwindling the duration of the procedure and the number of attempts than the conventional technique.

Key Words:

Tracheostomy, Ultrasound, Complications.

Introduction

One of the oldest and most common surgical procedures performed in ICUs is tracheostomy. Tracheostomy is most commonly performed for the indication of prolonged intubation. Complications of infection, laryngeal injury, vocal cord paralysis, glottic-subglottic stenosis, and tracheal injury (tracheomalacia, tracheal dilatation and tracheal stenosis) may occur due to prolonged intubation in ICUs[1]. Tracheostomy is applied to patients who are intubated in the ICU to reduce these complications, make the airway safe, improve patient comfort, initiate oral feeding, ensure pulmonary hygiene, and reduce mechanical ventilator support[2]. The tracheostomy is performed using a conventional surgical technique (surgical tracheostomy) or percutaneous dilatation tracheostomy (PDT). The most used tracheostomy technique in ICUs is PDT. PDT can be performed with one or a combination of traditional anatomic landmark percutaneous tracheostomy (Griggs technique, G-PDT), ultrasound-guided percutaneous dilatational tracheostomy (U-PDT), and bronchoscopy-guided percutaneous dilatational tracheostomy (B-PDT). Currently, the Griggs technique, which is the most common traditional anatomic landmark percutaneous tracheostomy method, is used[3]. PDT provides potential benefits for the patient, such as increased patient comfort, reduced sedation requirements, and reduced dead space[4]. Us-

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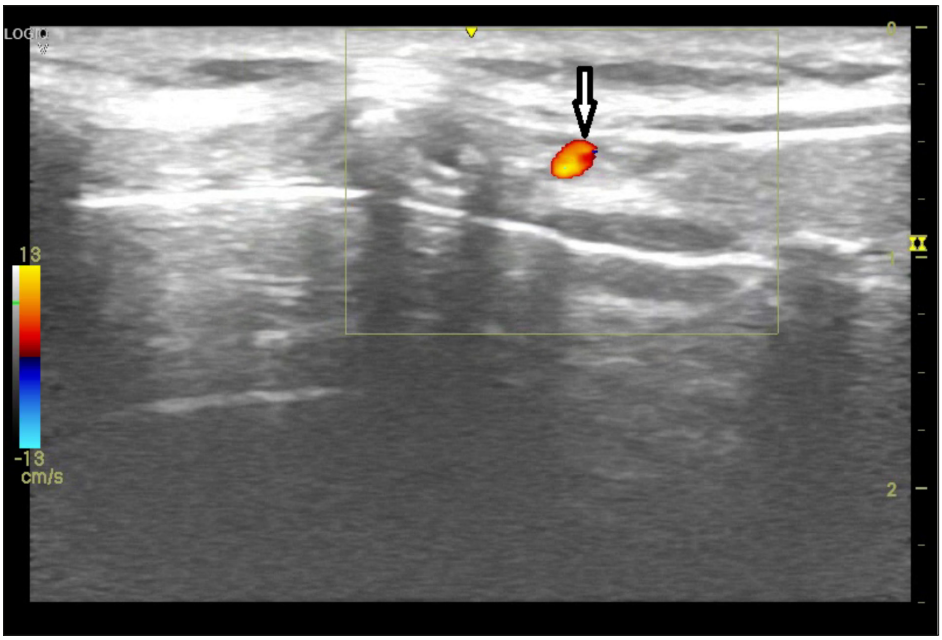

Figure 1. Vascular structures seen on ultrasound.

ing a US or bronchoscope as an adjunct to PDT reduces the likelihood of process failure and complications[4]. Upper airway anatomy, vascular structures, and other tissues (such as the thyroid) cannot be evaluated with G-PDT and B-PDT techniques. B-PDT is the only technique for real-time visual confirmation of the needle entry point, the midline position of the needle, and particularly to prevent posterior tracheal wall injury[4,5]. Although B-PDT provides a real-time visual advantage, it is not superior to other methods in terms of reducing the complication rate.

In recent years, the US has been used in many practices ranging from diagnostic procedures to invasive procedures in ICUs. With real-time U-PDT, upper airway anatomy and paratracheal structures (such as vascular, thyroid and esophagus) can be evaluated and the tracheal space for tracheostomy can be determined easily (Figure 1-2-3). The use of US in PDT increases the chance of success of the procedure, reduces complications and mortality and allows tracheostomy to be performed more easily at the bedside[1,6,7]. Compared to surgical tracheostomy, PDT has advantages, such as being able to be performed at the bedside, preventing complications that may occur during the patient's transportation to the operating room, and reducing costs[3,8]. Gadkaree et al[9] detected an increase in airway resistance and complications due to high airway pressure during B-PDT. Besides, bronchoscopy is the most challenging of PDT procedures regarding patient safety and cost[10]. Ultrasound and bronchoscopy are helpful tools for optimizing the performance of the PDT procedure. The US can be used to identify skin and subcutaneous vascular structures, select the procedure site, assist in the accurate placement of the introducer needle during the procedure, and detect post-procedure pneumothorax[11]. On the other hand, all methods have pros and cons over each other as well.

In this study, Grigg and ultrasound-guided percutaneous dilatation tracheostomy methods applied at the bedside in the ICU were compared regarding procedural success and complications.

Patients and Methods

This study was conducted retrospectively at Hitit University Erol Olçok Training and Research Hospital after the approval of the Local Ethics Committee (December 11th, 2019:108) and Clinical trials identifier number is NCT05514613. The files of 2,852 patients who were followed up in the Level 3 Anesthesia ICU between April 2017, and March 2019 were reviewed. The findings showed that 102 patients had undergone tracheostomy under elective conditions and 43 patients who had undergone open surgery tracheostomy were excluded from this study. 59 patients who had undergone bad-side PDT were considered to be the study population. The patients were

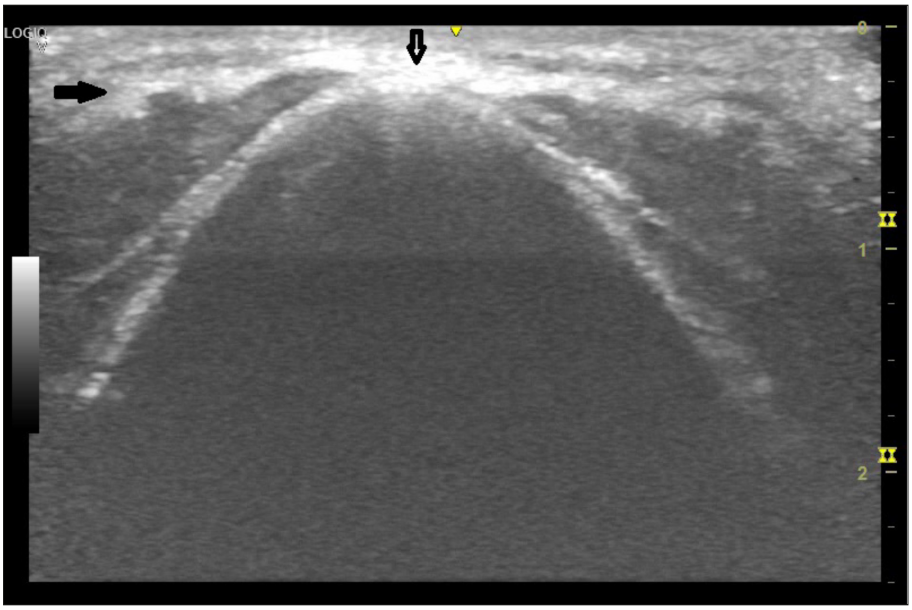

Figure 2. Thyroid tissue and Thyroid cartilage.

assigned into two groups those who underwent Griggs PDT Group G and those who underwent US-guided PDT Group U. A familiar anatomical landmark technique was used in all patients who underwent the Griggs technique[12]. US (GE Logiq V2 Portable Ultrasound System, Solingen, Germany)-guided tracheostomy was performed with the out-of-plane method and the guide wire was checked in the plane[3]. No patient needed to switch between the two methods or to switch to surgical tracheostomy. No patient with cardiac arrest or death was observed during the procedure or in the early period. Groups were compared regarding gender, body mass index (BMI),

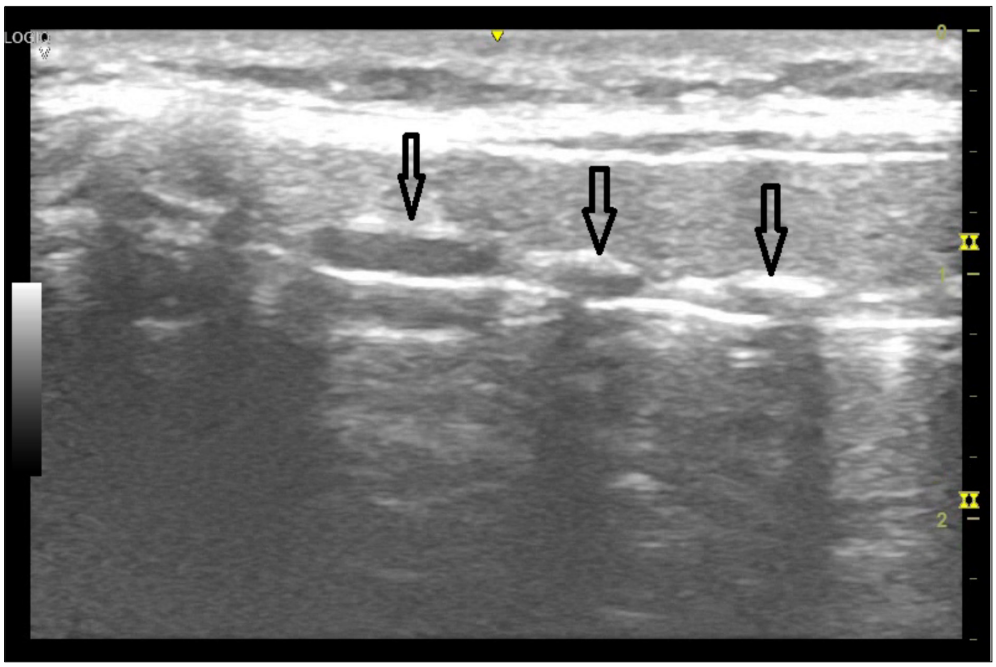

Figure 3. Tracheal rings.

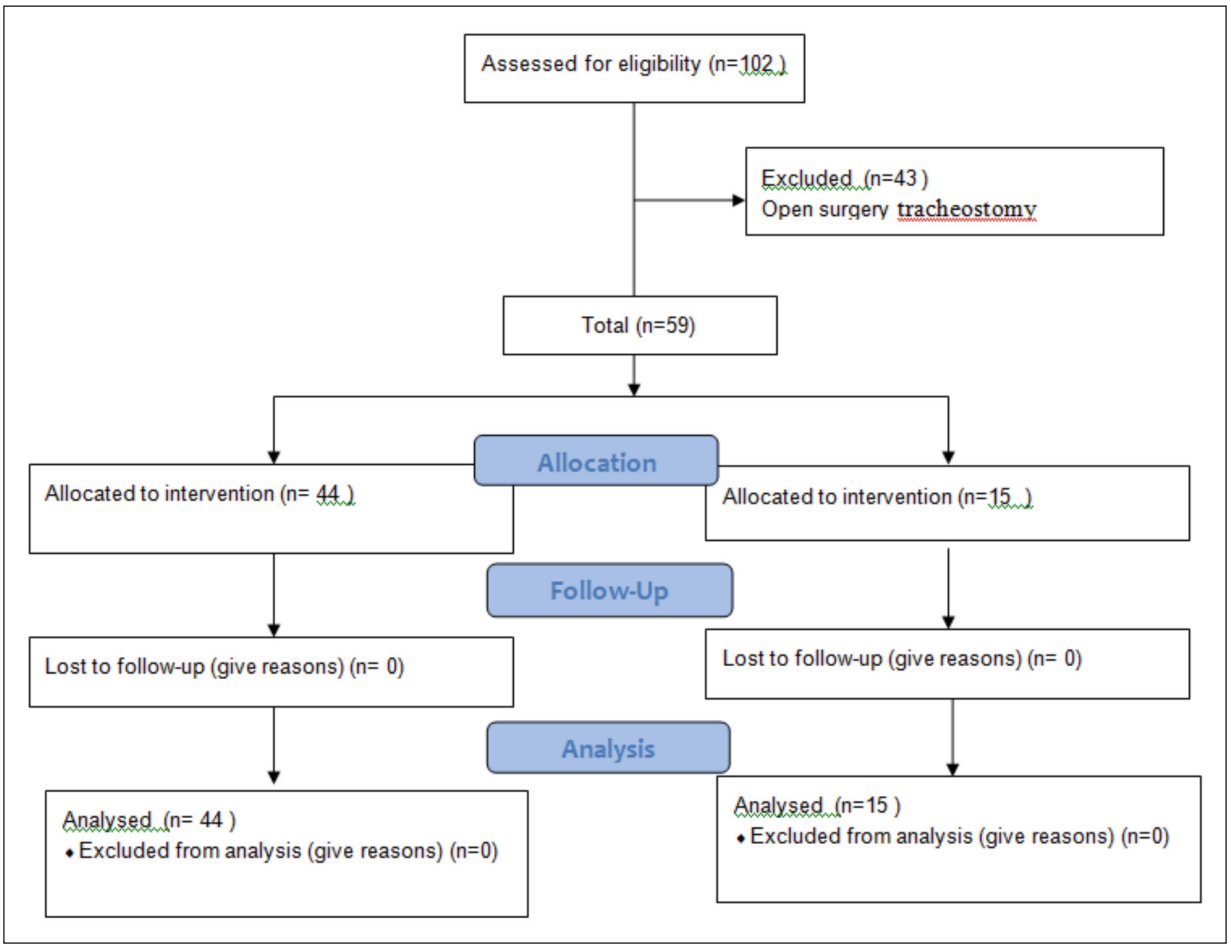

Figure 4. Consort diagram.

indication for hospitalization, Glasgow Coma Scale (GCS), laboratory data, mechanical ventilation (MV) requirement, the timing of PDT, blood transfusion requirement, and duration of ICU stay, discharge status, procedural features, and complications.

Statistical Analysis

Mean, Standard deviation, median, minimum, maximum, frequency, and ratio values were used in the descriptive statistics of the data. The Kolmogorov-Smirnov test was used to determine variable distribution. Descriptive statistics computed for the variables of interest included frequencies for categorical variables and median with interquartile range (IQR) for continuous variables. Bivariate associations of categorical variables with the outcomes of interest were tested using the Chi-square test or Fisher's exact test, as appropriate. Bivariate associations of continuous variables with the binary outcomes of interest were assessed using the Mann-Whitney U test. We calculated the effects of the independent variables on the dependent variable using the Eta squared correlation coefficient. Results were considered statistically significant where $p<0.05$. All calculations were made with standard commercial software (SPSS 24.0, IBM, Armonk, NY, USA).

Results

The data of 59 patients who had undergone PDT were analyzed. Group G consisted of 44 patients and Group U consisted of 15 patients. The mean age of all patients was 74.93 (+/-11.7). Of all patients, 21 were female and 38 were male. The mean BMI of all patients was 25.87 (std 4.85), and the mean GCS was 5.9 in Group G and 6.7 in Group U. No difference was determined between the groups regarding mean values of age, gender, GCS, and BMI. The indications for hospi-

Table I. Demographical status of all patients and comparison between two groups.

Variables	All Patients (n=59)	Group G (n=44)	Group U (n=15)	p
Gender (M/F), n (%)	38/21 (64.4/35.6)	31/13(70.45/29.54)	7/8 (46.66/53.33)	0.124
Age, years	74.93 (min:38/max:93)	75.05 (min:37/max:94)	74.6 (min:46/max:91)	0.515
BMI (mean/std)	25.87 (std:4.85)	25.25 (std:4.32)	27.7 (std:5.95)	0.259
GCS (mean)	6.14 (std:2.18)	5.93 (std:2.03)	6.73 (std:2.54)	0.728
Prognosis n/% (ex/alive)	50 (84.7%)/9 (15.3%)	38 (86.4%)/6 (13.6)	12 (80%)/3(20%)	0.554
Diagnosis (n)				
- CVD	31	10	21	
- COPD	11	1	10	
- CD	1	4	1	
- Trauma	2	0	2	
- Malignity	1	0	1	

Values are expressed as the mean (standard deviation), median [25th-75th percentiles], or number (percentage).

talization were as follows: Cerebro-vascular disease (CVD) was detected in 31 patients (52.5%), cardiovascular disease (CVD) in 14 patients (23.7%), Chronic Obstructive Pulmonary Disease (COPD) in 11 patients (18%), trauma in two patients (3.4%) and malignancy was detected in one patient (1.7%) (Table I). When tracheostomy indications were examined, it was found that 50 patients underwent PDT due to neurological diseases, insufficient spontaneous respiratory effort and low GCS, and 9 patients underwent PDT after re-intubation due to unsuccessful weaning. When all patients were evaluated, it was determined that tracheostomy was scheduled for 33 days (min:-max= 4-100 days) after intubation. When the data were analyzed, Group U 3 and Group G 6 patients alive and were being followed up in the ICU. Other patients had died. There were no patients discharged or excluded from intensive care. Mechanical ventilation support was continued in all patients who had undergone a tracheotomy. No exitus occurred during all PDT procedures.

The mean hospitalization duration of all patients after tracheostomy was 60.83 days (std 45.5). The mean duration of tracheostomy procedures was 11.07 minutes in all patients (std 3.42 and range: 5 min-18 min). When the groups were analyzed separately in terms of tracheostomy duration, it was determined that tracheostomy was completed in an average of 12.64 minutes in Group G and an average of 6.47 minutes in Group U (Table II). The tracheotomy duration of Group U was significantly shorter than Group G (p= 0.000). The mean number of entries to penetrate the trachea was 2.2 times (+/-0.9) in all patients. In Group G, the trachea could not be reached at all in the first entry. The number of tracheal penetrations in Group G was 23 at the second entry, 16 at the third entry, and 5 at the fourth entry. On the other hand, penetration was achieved in the first entry in 14 patients and the second entry in 1 patient in Group U. The tracheal penetration rate was 93.33% in the first entry in Group U, this rate was 0% in the first entry in Group G, and this rate increased to 52.27% in the 2nd entry. In Group G, the successful penetration rate increased to 88% at the 4th entry but had a lower success rate than the Group U at the 2nd entry. No procedure failure was observed in either group (Table III).

None of the patients in Group U had hypoxemia during tracheostomy, whereas hypoxemia occurred in seven patients in Group G. The inci-

Table II. Tracheostomy data.

	Group G (n=44) Mean	Group U (n=15) Mean	p
Tracheostomy time (day)	32.7	37.0	.727
Number of punctures	2.59	1.07	*.000**
Success of the first entry (n/%)	0 / 0	14 /93.33%	*.000**
Total period (min)	12.64	6.47	*.000**

*Independent samples + Chi^2 tests. The mean difference is significant at the level of 0.05.

Table III. Success of the entry n (%).

	Group G	Group U
First entry	0	14 (93.33%)
Second entry	23 (52.3%)	1 (6.7%)
Third entry	16 (36.4%)	0
Fourth entry	5 (11.4%)	0

dence of hypoxemia in Group U was significantly lower ($p = 0.011$). Hypercapnia was not observed in any patient in Group U during tracheostomy, whereas it was observed in 11 patients in Group G. Hypercapnia was significantly higher in Group G than Group U ($p = 0.000$). Minor bleeding occurred in 1 patient in Group U and 4 patients in Group G. Moderate bleeding (with hemogram changes but not requiring transfusion) was observed in 1 patient Group U and was observed in 12 patients in Group G. Although major bleeding occurred in 11 patients in Group G, no major bleeding was detected in Group U. In addition, in total, bleeding was observed in 27 patients in Group G, while bleeding was detected in only 2 patients in Group U and bleeding was significantly more common in Group G ($p = 0.022$). When all the complications were evaluated, 62.7% of the patients had complications. The incidence of any complication was significantly higher in Group G than in Group U ($p<0.05$). The total number of complications (including more than one complication in the same patient) was 50 in Group G and 2 in Group U (Table IV). While tracheal stenosis, hoarseness, infection, mediastinitis, tracheal injury, aspiration, tracheomalacia, paratracheal location and death were not observed in all patients, bleeding, hypoxemia and hypercapnia were the most common complications.

Discussion

We aimed to compare the first-pass success, complication incidence, bleeding rate and duration of tracheostomy procedure between the G-PDT using anatomical landmarks and the U-PDT in our ICU tracheostomy patients. Rudas et al[13] reported a higher first-pass success rate and a reduced complication rate in comparison with landmark PDT in their study in which they described the advantage of using the landmark PDT in US-guided PDT procedure, identification of neck anatomy, midline, trachea, thyroid, and cricoid ring with the probe, real-time visualization of the plane between tracheal rings, real-time tracheal puncture with out-of-plane technique, guide wire placement and dilatation, as control after insertion of the tracheostomy tube.

Likewise, in our study, the Group U was significantly superior regarding first pass success and tracheal penetration. In particular, the first penetration rate was 93.33% in the Group U. Access to the trachea in the first pass after the anatomical examination was never achieved.

Yavuz et al[14] reported a shortening of the duration of the tracheostomy procedure, a high first pass success rate and a reduced complication rate in their study in which they compared Landmark-PDT (L-PDT) in U-PDT procedures.

Kupeli et al[15] in their randomized controlled comparative study of the in-plane and out-of-plane U-PDT technique and the L-PDT technique, found that the US-guided procedure had fewer punctures, a higher first pass success rate and fewer complications. It has been documented that advanced age adversely affects the success of the first entry and the complication rate increases as the number of punctures increases.

Table IV. Complications n (%).

Complications n (%)	GRUP G	GRUP U	p
Minor bleeding	4 / (9.09%)	1 / (6.66%)	Totally
Moderate bleeding	12 / (27.2%)	1 / (6.66%)	.022*
Major bleeding	11 / (25%)	0	
Pneumothorax	1 / (2.27%)	0	1.000
Emphysema	1 / (2.27%)	0	1.000
hypoxemia	7 / (15.9%)	0	.024*
Hypercapnia	11 / (25%)	0	.002*
Esophageal injury	3 / (6.8%)	0	.564

*Independent samples + Chi^2 tests. The mean difference is significant at the level of 0.05.

Besides, Dinh et al[16] in their study comparing U-PDT and L-PDT, reported a short tracheostomy procedure time, high first pass success rate and reduced complication rate, similar to other studies.

The time from the percutaneous penetration of the needle to the insertion of the tracheostomy tube was defined as the total duration of tracheostomy. Yavuz et al[14] noted in their study that calculating the total duration of tracheostomy insertion from the beginning of the ultrasound scan in UGT or the beginning of physical palpations in L-PDT is waived, not skin penetration. In the study in which Gobatto et al[17] compared US-PDT and B-PDT, the mean Tracheostomy Duration was 12 and 15 minutes, respectively. In our study, we found the mean Tracheostomy Duration in all patients was 11.07 minutes. However, the mean duration of tracheostomy was 6 minutes in Group U in our study, and it was shorter than the US-PDT group in Gabotto et al[17] study. The reason for the difference in the duration of tracheostomy between the two studies might arise from the experience difference between the practitioners. Gobatto et al[17] noted the anatomical difficulty in 6% (i.e., 3 patients) of patients who underwent US-PDT. This indicates that the patient-related factors at US-PDT affect the Tracheostomy Duration as much as the practitioner-related experience. In our study, after the neck anatomy scan with the US and the necessary markings were made, the time from the out-of-plane needle entry to the insertion of the tracheostomy cannula into the trachea was recorded. In the landmark technique, meanwhile, after the neck was manually examined, the entry site was determined and marked. The time from needle entry to insertion of the tracheostomy cannula into the trachea was recorded. In our study, however, examination and US scanning times are not included in the tracheostomy duration. Thus, it can explain the shorter tracheostomy duration values in our study than other studies.

In some meta-analysis[11,18] studies comparing real-time US-PDT and L-PDT techniques, it was shown that US-PDT was associated with a high first-pass rate and a significant reduction in all-cause complications when first-pass success and complications were examined. In the same meta-analysis[11,18] studies, it was stated that there was no significant reduction in major bleeding.

In our study, we obtained results supporting the studies in which PDT was performed using the out-of-plane technique guided by the real-time US. We found that the duration of the tracheostomy procedure was shortened by 50% in the US-PDT group and complication rates reduced significantly.

Ultrasound can well identify the skin, percutaneous and tracheal ring, and as it determines the vascular anatomy, it can prevent vascular injury and reduce the risks of major bleeding. It has been suggested that the user-level evaluation of the images obtained from the US and the sufficient sono-anatomy knowledge of the practitioner increase the success of the procedure[5].

In some retrospective reviews[19,20], the rate of bleeding associated with a percutaneous tracheostomy was 4.8% in a systematic review, the fatal complication rate was 0.17%, and bleeding was the most common cause of death in L-PDT. In another meta-analysis, it was reported that US-PDT did not significantly reduce the occurrence of major bleeding than L-PDT.

In our study, a significant decrease was found in the US group in total bleeding complications, including major bleeding. This result is expected to significantly reduce the need for blood transfusion in the US-PDT group. Hence, a prospective study can be conducted for complications of late bleeding complications and blood product-related replacement therapy.

The incidence of minor bleeding was present in 11 (18.3%), Hypoxemia 2 (3.3%), and major bleeding 3 (5%) patients treated with L-PDT by Fikkers et al[21]. Moreover, in the study performed by Yaghoubiet al[22] with L-PDT and without using US and bronchoscopy, the incidence of minor bleeding was 0 (0%), hypoxemia 1 (1.4%) and major bleeding 3 (4.2%).

In our study, the frequency of minor bleeding was 4 (9.09%), hypoxemia 7 (15.9%) and major bleeding 11 (25%) in Group G. In Group U, the frequency of minor bleeding was 1 (6.6%), moderate bleeding 1 (6.6%) hypoxemia 0 (0%) and major bleeding 0 (0%) patients. Obtaining statistically varying results in different studies may be due to personal differences and patient characteristics. Besides, the number of patients in studies should be increased to obtain clearer results. For these reasons, varying results are obtained among all studies. To obtain statistically clear results in PDT studies, patients and evaluation criteria should be more universal, the number of patients in the study population should reach an adequate number and the study should be designed multi-centered; however, meeting these conditions is extremely challenging.

Rudas et al[13] showed that the use of US significantly increased the success of first pass puncture

in a study in which B-PDT was applied to both groups (classical landmark *vs*. US assisted). They also revealed that the use of US reduced complications. In our study, the first penetration rate in the use of US was 93.33%. However, the first penetration was not successful in the L-PDT method. In the L-PDT group, even in the 4th entry (88%), the success rate of Group U in the first entry could not be reached. Rudas et al[13] increased the probability of first penetration to 58% in the landmark technique with the use of bronchoscopy. In our study, we could remarkably increase our chances of first penetration when bronchoscopy was used. In Rudas et al[13] study, the first penetration success was 87% in the US group. In our study, this rate was 93.33%. This suggests that bronchoscopy is not required to increase the success of first penetration in US-PDT procedures.

The incidence of Pneumothorax in tracheostomies varies considerably depending on the techniques performed (from 0% to 17% (1-3) (0-7% in adults, 10-17% in children)[23]. Rudas et al[13] compared the effectiveness of US and landmark techniques in tracheotomy. In this study, pneumothorax was not observed in both the US group and the landmark group. Yaghoubi et al[22] did not encounter pneumothorax in the study in which he used the landmark technique and did not receive assistance with bronchoscopy. In our study, pneumothorax was observed in one patient in Group G, but pneumothorax was not encountered in any patient in Group U. Also, the use of the US reduces the incidence of pneumothorax but expanding the study population will allow us to obtain clearer results in determining the impact of the guidance of the US on the incidence of pneumothorax. In addition, in respiratory diseases such as Tuberculosis and COVID-19, aerosol-forming procedures such as tracheostomy; we think that US-guided PDT, which is a method that increases the success of the procedure, shortens the procedure time and reduces complications such as hypoxemia, can be used for the safety of both patients and healthcare professionals[24-26].

The main limitation of this study is the limited number of patients. We think that it is necessary to increase the number of patients in order to clarify the complication rates.

Conclusions

We recommend using US during the PDT procedure since the use of ultrasound in percutaneous tracheostomies opened under elective conditions in the ICU reduces the duration of the procedure, the number of attempts and risk of hypoxemia, hypercapnia and bleeding than the conventional technique.

Conflict of Interest

The authors have no conflicts of interest to declare.

Ethics Committee Approval

The study was carried out with the permission of Hitit University Medicine of Faculty Hospital after the approval of the Local Ethics Committee (December 11th, 2019:108)

Informed Consent

All patients signed the free and informed consent form.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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