Original Article

Comparison of landmark guided and ultrasound guided percutaneous dilatational tracheostomy: Efficiency, efficacy and accuracy in critically ill patients

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Abstract

Background and Aims: To overcome the procedure-related complications associated with landmark-guided percutaneous dilatational tracheostomy (PDT) ultrasound is emerging as a promising tool. Present study was designed to compare landmark-guided PDT and ultrasound-guided PDT in terms of efficiency, efficacy, and accuracy.

Material and Methods: Hundred intensive care unit patients requiring prolonged mechanical ventilation were prospectively randomized into 2 groups of 50 patients each. In land mark guided (LMG) group, patients underwent landmark-guided PDT, whereas in ultrasound guided (USG) group, patients underwent ultrasound-guided PDT.

Results: Both the groups were comparable in terms of demographic data, sequential organ failure assessment score, ventilator settings, and mean days on mechanical ventilation prior to PDT. The mean assessment time in the ultrasound-guided group (1.56 ± 1 min) was significantly more (*P*-value = 0.000) than in the landmark-guided group (0.84 ± 0.72 min). The mean total procedure time for the USG group (5.98 ± 10.23 min) was more than that for the LMG group (4.86 ± 8.03 min) (*P*-value 0.542). Deviation of puncture site from the midline was seen in two patients in group A as compared to none in the USG group (*P*-value = 0.153). The number of patients requiring more than one attempt for successful needle insertion was more (*P*-value = 0.148) in the LMG group (20%) as compared to USG group (8%). Incidence of complications, like bleeding and desaturation was more in the LMG group as compared to the USG group.

Conclusion: Ultrasound-guided PDT is associated with reduction in periprocedural complications as compared to landmark technique, although it takes slightly longer time.

Keywords: Grigg's technique, landmark guided, percutaneous dilatational tracheostomy, ultrasound guided

Introduction

Percutaneous dilatational tracheostomy (PDT) is routinely performed in intensive care units. Palpation of anatomical landmark is traditionally used to guide the insertion of the puncture needle. Surface landmarks may give limited clarity of underlying anatomy in many cases. Palpation technique has a low accuracy in predicting correct placement and it may be associated with acute complications like loss of airway during procedure, posterior tracheal wall injury, life-threatening bleeding, hematoma formation, pneumothorax, pneumomediastinum, and creation of false passage.[1,2]

To overcome these difficulties encountered with use of landmark as guidance during PDT, use of periprocedural ultrasonographic guidance appears promising.[3,4] Periprocedural ultrasonography has the potential to improve the

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efficacy and decrease the complications associated with PDT. However, the application of real-time ultrasound-guided PDT has so far been mainly limited to be descriptive observational studies and very few comparative randomized controlled trials are available.[5–7] We compared landmark-guided PDT and ultrasound-guided real-time PDT in terms of accuracy, efficacy, and efficiency.

Material and Methods

After approval by institutional research and ethical committee, 100 intensive care unit patients of either sex, aged 18 years or above, on prolonged mechanical ventilation because of respiratory failure, critical illness, polyneuropathy or bulbar dysfunction, upper airway obstruction, trauma, mass or infection in oral cavity, pharynx, or larynx, and unprotected airway due to poor neurological status, scheduled to undergo tracheostomy were enrolled in this study. Patients with uncontrolled coagulopathy, local infection, burns, wound or trauma on anterior neck, unstable cervical spine fracture, or any other anatomical contraindication for performing tracheostomy were excluded from the study. Patients were prospectively randomized to 2 groups of 50 patients each using computer-generated random numbers as:

Group LMG: underwent landmark guided PDT.

Group USG: underwent ultrasound assisted PDT.

A thorough preprocedure assessment including routine investigations including hemogram, renal function tests, prothrombin time index, and arterial blood gas analysis were done as per institutional protocol. Sequential organ failure assessment (SOFA) scoring was assessed and recorded for each patient. The procedure was explained and a written, informed consent was obtained from the patient/legal guardian as appropriate.

Continuous standard multiparameter monitoring with pulse oximeter, noninvasive blood pressure, heart rate, and electrocardiogram (ECG) monitoring was initiated. Intravenous access was ensured. Immediate access to suction equipment, end tidal carbon dioxide monitoring, and ambu bag for manual ventilation of patient was also ensured. Patients were ventilated with 100% oxygen for about 5 min before start of procedure. Following appropriate sedation (midazolam 0.1 $mgkg^{-1}$), analgesia (fentanyl 2 μgkg^{-1}), and neuromuscular relaxation (atracurium 0.4 $mgkg^{-1}$), position of patient was made with pillow under the shoulders to extend neck, to facilitate identification of landmarks and procedure performance. Aseptic preparation and draping of the anterior neck was done. PDT was performed by an experienced intensivist (more than 50 ultrasound-guided PDT independently) as per allocated group using Grigg's guide-wire dilating forceps (GGDF).

In the LMG group, anatomical landmarks were used to guide the tracheal puncture. The suprasternal notch, thyroid cartilage, cricoid cartilage, and tracheal rings were identified. If the tracheal rings were difficult to palpate, midpoint between the cricoid cartilage and suprasternal notch was then used as puncture site. In the USG group, real-time ultrasound guidance was used to identify the thyroid gland, cricoid cartilage, cricothyroid membrane, and tracheal rings using both midline longitudinal and transverse view [Figures 1 and 2]. Color Doppler was used to visualize vascular structures in the operative area to identify a safe puncture site.

In both the groups, subcutaneous infiltration with 3–5 ml of 2% lidocaine with adrenaline (1:200,000) was done. A 1–2 cm transverse skin incision was made and blunt dissection of pretracheal tissues was performed. In the LMG group, anterior trachea was palpated and the intended puncture site was identified. In the USG group, transverse probe position and real-time out-of-plane technique was used to guide the tracheal needle puncture [Figure 3]. To improve ultrasonic view in real time, incision wound was irrigated with normal saline. Trachea was punctured with a 14-gauge cannula-on-needle in a posterior caudal direction and tracheal entry of the needle was confirmed by aspiration of air into the saline-filled syringe. Level of tracheal puncture and any deviation of puncture site from midline were noted using ultrasound in both the groups. "J" tip guide wire was passed through the cannula and the cannula was removed and the track was dilated with dilator. Then, GGDF was inserted and aligned in the long axis of the trachea for dilation of the anterior wall of the trachea. The GGDF was then removed leaving the guide wire *in situ*. A cuffed tracheostomy tube with fenestrated obturator was advanced over the guide wire. The obturator and guidewire were then removed. Correct placement of the tube and verification of appropriate breath delivery by ventilator was confirmed by chest auscultation and monitoring of $EtCO_2$ tracing.

Time after cleaning and draping to the skin incision was noted as assessment time. Time from skin incision to the placement and confirmation of the tracheostomy tube was noted as procedure time. The two techniques were compared in terms of efficiency, efficacy, and accuracy. Efficiency was assessed by the total time taken for the procedure (assessment time and procedure time). Accuracy was assessed by deviation of the needle puncture from the midline and site/level of needle puncture/insertion. Efficacy was assessed by number of attempts for successful and uneventful needle puncture,

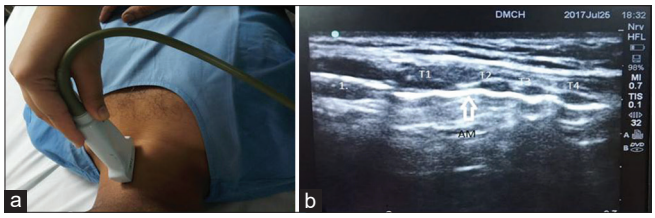

Figure 1: (a) Longitudinal probe position in the midline of the neck (sagittal plane). (b) Sonoanatomy of neck with the ultrasound probe held in midline in sagittal plane .T1 = first tracheal ring, T2 = second tracheal ring, T3 = third tracheal ring, T4 = fourth tracheal ring, 1 = Cricoid cartilage, and AM = air mucosa interface

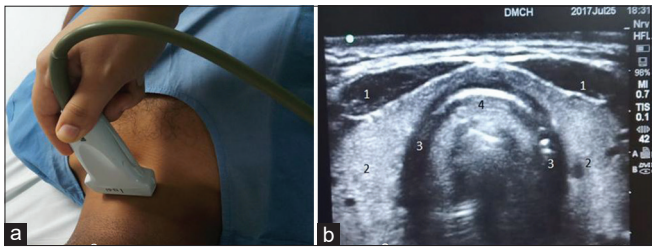

Figure 2: (a) Transverse probe position. (b) Sonoanatomy in transverse probe position. 1 = strap muscles, 2 = thyroid cartilage with thyroid isthmus, 3 = tracheal ring, and 4 = air mucosa interface

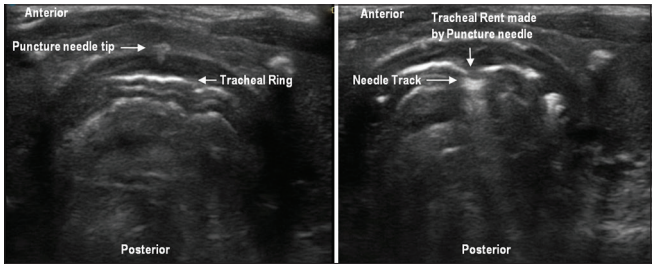

Figure 3: Intraprocedural USG neck: out of plane technique and probe in transverse position

number of attempts for successful and uneventful tracheostomy tube insertion, and incidence of associated complications.

Statistical analysis

Statistical analysis was conducted using the SPSS (version 17, 2006, SPSS Inc., Chicago, IL, USA) for Windows statistical package. Mann–Whitney *U* test was used for comparison of continuous or ordinal variables. Chi-square ($\chi 2$) test was used for comparison of dichotomous or nominal variables.

Power Analysis: A post hoc power analysis was conducted using G*Power software package. The alpha level used for this analysis was $P < 0.05$ and beta was 0.20. The post hoc analyses revealed the statistical power of 0.40 for this study for detecting a small effect, whereas the power exceeded 0.99 for the detection of a moderate to large effect size. Thus, there was more than adequate power (i.e., power >0.80) at the moderate to large effect size level, but less than adequate statistical power at the small effect size level.

By using study done by Rudas *et al.* as a template and using the first pass puncture parameter and we expected similar results, power came out to be 1 and with effect size of 0.86 with 10% chance of error.[5] The sample size of 100 patients was taken, with 50 patients each in 2 groups.

Results

In this study, a total of 120 patients were assessed for eligibility and finally 100 patients divided in 2 groups of 50 patients each were analyzed. [Figure 4—consort diagram]. There was no statistically significant difference between two groups with respect to age, height, weight, body mass index, neck circumference, sternomental distance and thyromental distance, SOFA score, ventilator settings, and mean days on mechanical ventilation prior to PDT ($P > 0.05$) [Table 1]. Indication for tracheostomy was poor Glasgow Coma Scale (GCS) due to neurological problems in 94% patients and respiratory failure in 6% patients.

The mean assessment time was significantly more (*P*-value = 0.000) in patients belonging to ultrasound-guided tracheostomy group (1.56 ± 1 min), as compared to landmark-guided tracheostomy group (0.84 ± 0.72 min). Although the mean procedure time in the LMG group (4.02 ± 7.85 min) was slightly less than that in the USG group (4.42 ± 10.25 min), but this difference was not statistically significant (*P*-value = 0.824). The mean total procedure time as calculated by sum of assessment time and procedure time in the USG group (5.98 ± 10.23 min) was more than that in the LMG group (4.86 ± 8.03 min) but again their difference was not statistically significant (*P*-value = 0.542) [Table 2].

Difficulty in identification of the landmarks clinically was encountered in 72% patients in the LMG group, as compared to 76% patients in the USG group. This difference was not statistically significant (*P*-value = 0.648).

In the LMG group, needle insertion was between the first and second tracheal rings (T1-2) in 6% patients, it was between second and third tracheal rings (T2-3) in 30% patients, whereas in remaining 64% patients, it was between the third and fourth tracheal rings (T3-4). In the USG group, the needle insertion was between second and third tracheal rings (T2-3) in 12% patients, whereas in remaining 88%, it was between the third and fourth tracheal rings (T3-4). In no case, the needle insertion between the first and second tracheal rings (T1-2) was noted in the USG group (*P*-value = 0.003) [Figure 5]. Deviation of more than 5 mm from the midline was seen in

Table 1: Demographic data, SOFA score, and days on mechanical ventilation in two groups

	Mean±SD		*t*	*P*
	Group A	Group B		
Age (years)	48.32±18.43	49.06±14.54	−0.223	0.824
Height (cm)	159.64±11.58	160.82±13.08	−0.478	0.634
Weight (kg)	65.54±12.13	65.26±10.00	0.729	0.690
BMI (kg/m^2)	25.80±4.34	25.83±5.27	0.639	0.710
Neck circumference (cm)	33.68±3.64	33.87±3.26	0.690	0.750
Sternomental distance (cm)	12.32±1.05	12.26±0.97	0.510	0.430
Thyromental distance (cm)	7.15±1.02	7.25±1.01	0.586	0.540
SOFA score	6.90±1.22	7.02±1.39	−0.459	0.647
Days on mechanical ventilation prior to tracheostomy	7.96±5.19	6.28±3.36	0.232	0.290

Data in table are mean±SD or number. BMI=Body mass index, SD=Standard deviation

Table 2: Assessment time, procedure time, and total procedure time in two groups

	Mean±SD		*t*	*P*
	Group A	Group B		
Assessment time (min)	0.84±0.72	1.56±1.00	−4.127	0.000
Procedure time (min)	4.02±0.85	4.42±10.25	−0.223	0.824
Total procedure time (min)	4.86±8.03	5.98±10.23	−0.611	0.542

Data in table are mean±SD. SD=Standard deviation

two patients in LMG group as compared to none in the USG group (*P*-value = 0.153).

Needle insertion was successful in single attempt in 46 patients (92%) in the USG group as compared to 40 patients (80%) in the LMG group. Although the number of patients requiring more than one attempt for successful needle insertion was more in the LMG group as compared to that in the USG group, these results were not statistically significant (*P*-value = 0.148) [Figure 6a].

More than one attempt for successful tracheostomy tube insertion was required in eight patients (16%) in the LMG group as compared to three patients (6%) in the USG group. This difference was not statistically significant (*P*-value = 0.110) [Figure 6b].

The incidence of minor bleeding which did not require active intervention was significantly less in the USG group (6%) as compared to the LMG group (22%) (*P*-value = 0.041). Bleeding during the procedure for which interventions were required to achieve hemostasis occurred in two patients (4%) in the LMG group, whereas no patient had significant bleeding requiring any intervention in the USG group, but this difference was statistically not significant (*P*-value = 0.495). Overall incidence of periprocedure complications was significantly more in the LMG group as compared to the USG group (*P*-value = 0.001) [Table 3].

Heart rate, systolic arterial blood pressure, mean arterial pressure, oxygen saturation, and respiratory rate were comparable in both the groups during the periprocedural period. [Figure 7]. None of the patients in either group developed complications like pneumothorax, tracheal injury, esophageal injury, and paratracheal tracheostomy tube placement.

Discussion

Ultrasonography has brought a fundamental change in the management of airway. With increasing awareness, portability, and accessibility, ultrasonography is likely to find place in routine airway management.[8] Airway ultrasound can help in visualization of tongue, oropharynx, hypopharynx, epiglottis, larynx, vocal cords, cricothyroid membrane, cricoid cartilage, trachea, and cervical esophagus.[9] Preprocedural use of ultrasonography for airway assessment and real-time ultrasound guidance during percutaneous tracheostomy can be a game changer in terms of safety and efficacy of the procedure.

We compared landmark-guided PDT and ultrasound-guided PDT in 100 critically ill patents on ventilatory support in terms of efficiency, efficacy, and accuracy. Efficiency was assessed by the total time taken for the procedure. We analyzed the procedure time in terms of assessment time and procedure time separately, which has not been done till date in any study.

In our study, the mean assessment time was significantly longer for ultrasound-guided group (B) than by the landmark-guided percutaneous tracheostomy group (A). The mean procedure time in the USG group was also more than that in the LMG group but it was not statistically significant. The mean total procedure time in the USG group (5.98 ± 10.23 min) was more than that in the LMG group (4.86 ± 8.03 min), but the difference was not statistically significant (*P*-value = 0.542). Similarly, in study by Yavuz *et al.*, the mean procedure times for the ultrasound group and the control group (landmark) were 24.09 ± 8.05 min and 18.62 ± 6.34 min, respectively.[10] Unlike our study, Dinh *et al.* in their study

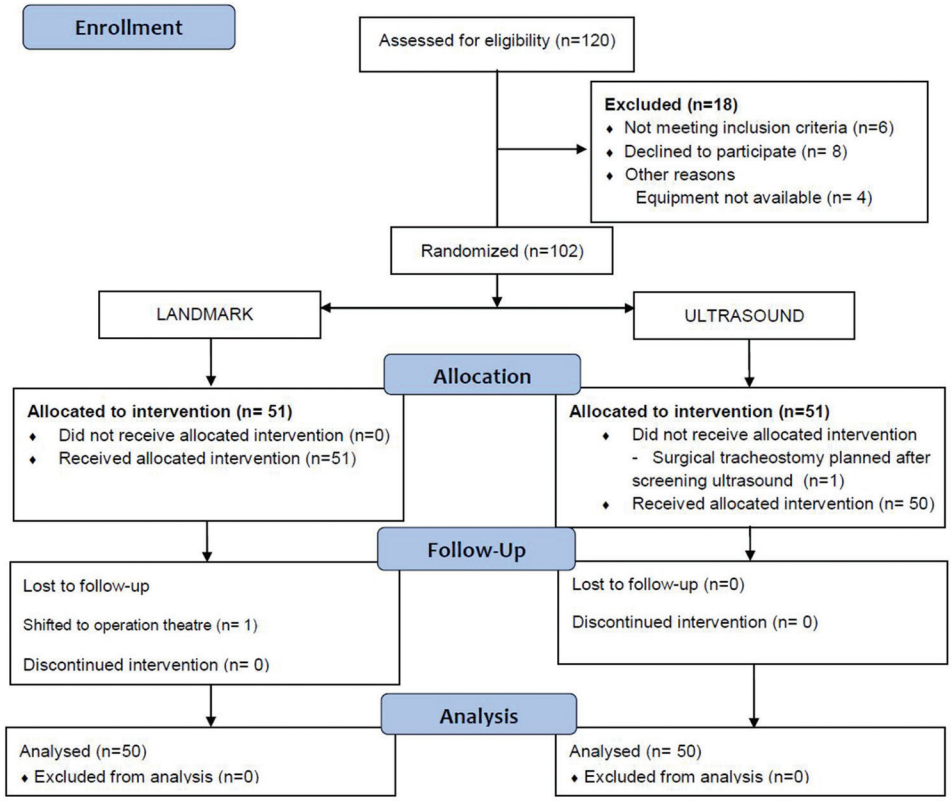

Figure 4: Consort flow diagram

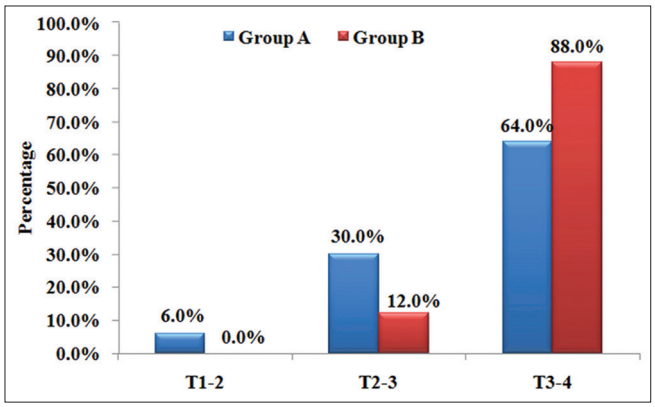

Figure 5: Site of needle insertion in both the groups

reported that the total tracheostomy time was 11.4 ± 4.2 min in the sonography group versus 15.3 ± 6.8 min in the landmark group (*P*-value = 0.12).[11] Song *et al.* reported ultrasound-guided percutaneous tracheostomy time of 12.8 ± 4.8 min in obese patients.[12] Petiot *et al.* demonstrated that ultrasound-guided PDT is associated with a fairly long learning curve.[13] These variations in the time taken for the procedure by ultrasound versus landmark-guided approach can be due to many factors namely the experience of the performer, single or more than one performer for the procedure, the type of assistance, the anatomy of the patient, the level of difficulty, etc.

Table 3: Periprocedural complications in two groups

Complication	Group		Chi-square value	*P*
	A	B		
Minor bleeding	11 (22.00%)	3 (6.00%)	5.316	0.041
Bleeding requiring intervention	2 (4.00%)	0 (0.00%)	2.041	0.495
Surgical emphysema	1 (2.00%)	0 (0.00%)	1.01	0.315
Desaturation	2 (4.00%)	1 (2.00%)	0.344	0.558
Ruptured ETT cuff	1 (2.00%)	0 (0.00%)	1.01	0.315
Total	17 (34.00%)	4 (8.00%)	10.186	0.001

The ideal location of the tracheostomy is between the second and third tracheal rings (T2-3) and the third and fourth tracheal rings (T3-4).[14] In our study, the needle insertion was between second and third tracheal rings (T2-3) in 30% cases in the LMG group, whereas in 64% cases, it was between the third and fourth tracheal rings (T3-4). In the USG group, needle insertion was between second and third tracheal rings (T2-3) in 12% cases, whereas in remaining 88% cases, it was between the third and fourth tracheal rings (T3-4). Tracheostomy between the first and second tracheal rings (T1-2) carries risk of perichondritis of the cricoid cartilage along with subglottis stenosis.[15] Low tracheostomy below the level of fourth tracheal ring level is rarely performed because

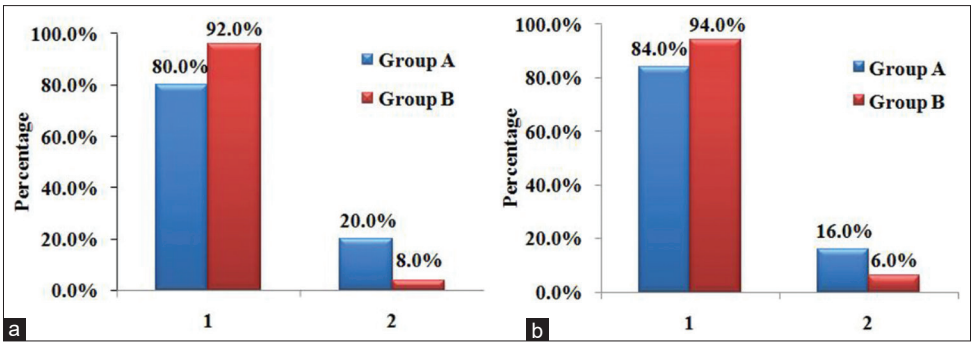

Figure 6: Number of attempts for (a) needle insertion and (b) tracheostomy tube insertion

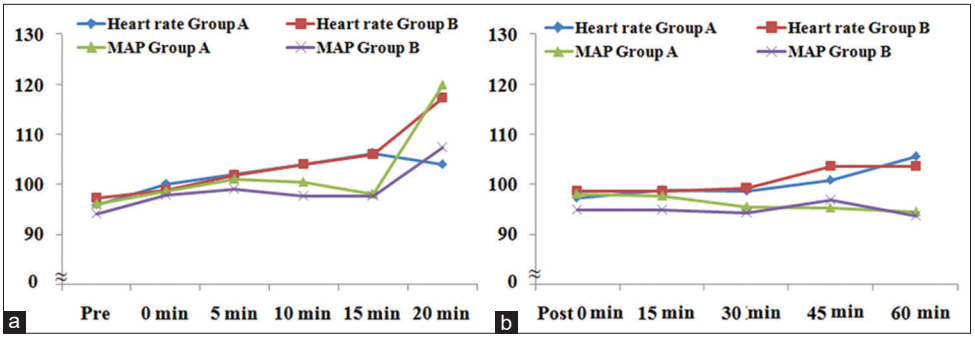

Figure 7: (a) Preprocedural and intraprocedural heart rate and mean blood pressure. (b) Postprocedural heart rate and mean blood pressure

of increased chances of injury to vessels and pleura.[14] In the USG group, no case of tracheal puncture between first and second tracheal rings was observed, whereas in the LMG group, 6% patients had tracheal puncture at this level.

Subjective assessment by the performer was done to note the deviation of puncture site from the midline (12 o'clock position) using ultrasound. In the LMG group, deviation from midline was observed in four cases (8%) as compared to no case of deviation from midline in the USG group. This difference was statistically insignificant. Only a few studies have compared deviation of puncture site from midline using ultrasound. Chacko *et al.* noted that puncture site on bronchoscopic view was median (between 11 o'clock and 1 o' clock positions) in 88.7% cases.[16] In a study conducted by Rudas *et al.*, mean midline deviation in the ultrasound and landmark groups was 15 ± 3° versus 35 ± 5° as assessed bronchoscopically (*P*-value 0.001).[5] This is in accordance with our study where no deviation from midline was seen in the USG group as assessed using ultrasound. Hence, in our study, the accuracy of the procedure was superior in ultrasound-guided technique as compared to landmark-guided technique as assessed by deviation of the needle puncture from the midline and site of needle puncture. Moreover, the use of ultrasound for assessing deviation of puncture site from midline obviates the need for dedicated person for doing periprocedural broncoscopy.

The comparative efficacy as assessed by number of attempts for successful and uneventful needle puncture, number of attempts for successful and uneventful tracheostomy tube insertion, and incidence of associated complications was more in ultrasound-guided technique (USG group) as compared to landmark-guided technique (LMG group).

The first pass success rate for needle puncture and tracheostomy tube insertion was greater in the USG group (92% and 94%, respectively) than in the LMG group (80% and 84%, respectively), indicating that the use of ultrasound improves the success of cannula insertion and tracheostomy tube placement with reduced number of attempts. In agreement to our study, Kupeli *et al.*, in their randomized controlled study, have reported that ultrasonography-guided out-of-plane application requires fewer number of puncture attempts, leading to higher first entry success rate, and less complications.[17] In a study conducted by Rudas *et al.*, first pass success rate was 87% in the ultrasound group and 58% in the landmark group.[5] Rajajee et al., in a feasibility study, demonstrated that real-time ultrasound guidance helps in more appropriate tracheal puncture site as confirmed by bronchoscopy.[2]

The most commonly encountered complication in our study was minor bleeding. Its incidence was significantly more in the LMG group (22%) as compared to the USG group (6%). Incidence of major bleeding requiring any interventions was more in the LMG group (4%) as compared

to the USG group (0%). In a study conducted by Rudas *et al*., 29% patients in the landmark-guided and 13% patients in ultrasound group had minor bleeding (*P*-value = 0.177). They also reported that 8% patients in the landmark-guided group and no patient in ultrasound group had bleeding requiring any intervention (*P*-value = 0.157).[5] Similar to our results, Yavuz *et al.* reported incidence of minor and major bleeding in 3.9% and 1.3% in ultrasound group and in 6.6% and 3.0% in landmark group, respectively.[10]

The incidence of other complications like desaturation, ruptured endotracheal tube cuff, and surgical emphysema was comparatively higher in the LMG group than in the USG group. Rudas *et al*. also reported overall 37% incidence of overall procedural complications in landmark-guided group and 22% in the ultrasound group.[5]

Limitations

We used a single-center design with limited number of cases, and need large multicenter trials with larger number of cases to avoid operator skill bias, patient anatomical and physical status bias, etc., We used ultrasound to check deviation of puncture site from midline; however, use of bronchoscopy would have helped in better visualization of deviation of puncture site from midline, any bleeding, tracheal mucosal injury and perforation of posterior tracheal wall, etc.

Conclusion

We conclude that, ultrasound guided PDT is associated with significant reduction in periprocedural complications like minor bleeding as compared to landmark technique. Ultrasound guided PDT is also associated with 12% better first pass success rate for needle puncture and 10% for tracheostomy tube insertion and also 4% higher success rate of midline puncture as compared to landmark guided technique but, at the cost of slight increase in total procedure time.

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Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Simon M, Metschke M, Braune SA, Püschel K, Kluge S. Death after percutaneous dilatational tracheostomy: A systematic review and analysis of risk factors. Crit Care 2013;17:R258. doi: 10.1186/cc13085.
2. Rajajee V, Williamson CA, West BT. Impact of real-time ultrasound guidance on complications of percutaneous dilatational tracheostomy: A propensity score analysis. Crit Care 2015;19:198.
3. Mallick A, Venkatanath D, Elliot SC, Hollins T, Nanda Kumar CG. A prospective randomised controlled trial of capnography vs. bronchoscopy for Blue Rhino percutaneous tracheostomy. Anaesthesia 2003;58:864-8.
4. Baumber R, Cohen A. Neck ultrasound prior to percutaneous tracheostomy: Should this now be a standard of practice? J Intensive Care Soc 2011;12:342.
5. Rudas M, Seppelt I, Herkes R, Hislop R, Rajbhandari D, Weisbrodt L. Traditional landmark versus ultrasound guided tracheal puncture during percutaneous dilatational tracheostomy in adult intensive care patients: A randomized controlled trial. Crit Care 2014;18:514.
6. Gobatto ALN, Besen BAMP, Tierno PFGMM, Mendes PV, Cadamuro F, Joelsons D, *et al*. Ultrasound-guided percutaneous dilational tracheostomy versus bronchoscopy-guided percutaneous dilational tracheostomy in critically ill patients (TRACHUS): A randomized noninferiority controlled trial. Intensive Care Med 2016;42:342-51.
7. Ravi PR, Vijai MN, Shouche S. Realtime ultrasound guided percutaneous tracheostomy in emergency setting: The glass ceiling has been broken. Disaster Mil Med 2017;3:7.
8. Garg R, Gupta A. Ultrasound a promising tool for contemporary airway management. World J Clin Cases 2015;3:926-9.
9. Singh M, Chin KJ, Chan VW, Wong DT, Prasad GA, Yu E. Use of sonography for airway assessment: An observational study. J Ultrasound Med 2010;29:79-85.
10. Yavuz A, Yilmaz M, Goya C, Alimoglu E, Kabaalioglu A. Advantages of US in percutaneous dilatational tracheostomy; randomized controlled trial and review of the literature. Radiology 2014;273:927-36.
11. Dinh VA, Farshidpanah S, Lu S, Stokes P, Chrissian A, Shah H, *et al*. Real-time sonographically guided percutaneous dilatational tracheostomy using a long-axis approach compared to the landmark technique. J Ultrasound Med 2014;33:1407-15.
12. Song J, Xuan L, Wu W, Zhu D, Zheng Y. Comparison of percutaneous dilatational tracheostomy guided by ultrasound and bronchoscopy in critically ill obese patients. J Ultrasound Med 2018;37:1061-9.
13. Petiot S, Guinot PG, Diouf M, Zogheib E, Dupont H. Learning curve for real-time ultrasound-guided percutaneous tracheostomy. Anaesth Crit Care Pain Med 2017;36:279-83.
14. Rudas M. The role of ultrasound in percutaneous dilatational tracheostomy. Australas J Ultrasound Med 2012;15:143-8.
15. Ravi PR, Vijay MN. Real time ultrasound-guided percutaneous tracheostomy: Is it a better option than bronchoscopic guided percutaneous tracheostomy? Med J Armed Forces India 2015;71:158-64.
16. Chacko J, Nikahat J, Gagan B, Umesh K, Ramanathan M. Real-time ultrasound-guided percutaneous dilatational tracheostomy. Intensive Care Med 2012;38:920-1.
17. Kupeli I, Nalbant RA. Comparison of 3 techniques in percutaneous tracheostomy: Traditional landmark technique; ultrasonography-guided long-axis approach; and short-axis approach - Randomised controlled study. Anaesth Crit Care Pain Med 2018;37:533-8.