BMC Anesthesiology

SYSTEMATIC REVIEW Open Access

Effectiveness of ultrasound-guided versus anatomical landmark-guided percutaneous dilatational tracheostomy: a systematic review and meta-analysis

Dan Wen[1†], Xiuru Yang[1†], Zhenghua Liang[1], Yang Hu[1], Simei Wang[1], Dan Zhang[1], Yao Wang[1], Yuqi Shen[1] and Fenglin Yan[1*]

Abstract

Background Percutaneous dilatational tracheostomy (PDT) is increasingly used in intensive care units owing to its advantages of reduced surgical trauma and fewer complications. Recently, ultrasonography has become a potentially useful tool for assisting PDT.

Objective To compare ultrasound- and landmark-guided PDT for major bleeding, first-puncture success rates, periprocedural complications, and tracheotomy procedure times.

Methods Randomized controlled trials (RCTs) or non-RCTs comparing ultrasound- and landmark-guided PDT were searched for in PubMed, Web of Science, MEDLINE, CINAHL, Cochrane Library, Wanfang Data Knowledge Service Platform, China National Knowledge Infrastructure (CNKI) and the Chinese Biomedical Literature Service System (SinoMed). The primary outcomes were major bleeding and first puncture success rate. Secondary outcomes were periprocedural complications and the tracheotomy procedure time. The meta-analysis was performed using RevMan 5.3 software.

Results This meta-analysis included five RCTs and one non-RCT, with a total of 609 patients. Compared with landmark-guided PDT, ultrasound-guided PDT can reduce the incidence of major bleeding (odds ratio [OR] = 0.35, 95% confidence interval [CI; 0.14, 0.90], $P = 0.03$) and improved the success rate of first puncture (OR = 4.41, 95% CI [2.54, 7.65], $P < 0.000001$). Additionally, ultrasound-guided PDT is associated with a lower incidence of periprocedural complications (OR = 0.35, 95% CI [0.22, 0.54], $P < 0.00001$). However, there was no advantage in reducing the tracheotomy procedure time between the two methods (mean difference = −0.64, 95% CI [−4.14, 2.85], $P = 0.72$).

†Dan Wen and Xiuru Yang made equal contributions to this manuscript

*Correspondence:
Fenglin Yan
smallwen123@126.com

Full list of author information is available at the end of the article

Conclusion Compared to landmark-guided PDT, ultrasound-guided PDT can reduce the incidence of major bleeding and periprocedural complications and increase the success rate of the first puncture. However, the advantage of ultrasound-guided PDT in reducing the tracheotomy procedure time is unclear.

Keywords Tracheostomy, Ultrasound, Intensive care unit, Anatomical landmark

Introduction

Tracheostomy is one of the most common procedures performed in the intensive care unit, with more than 100,000 patients undergoing tracheostomy each year in the United States [1]. Airway protection or long-term ventilator dependence are common indications for tracheostomy [2]. Tracheostomy has the advantages of reduced use of sedatives, easy oral care, preservation of swallowing function, and increased patient comfort [3]. First described by Ciaglia et al. in 1985, percutaneous dilatational tracheostomy (PDT) has become the standard bedside tracheostomy [4]. Compared with traditional tracheostomy, percutaneous dilatational tracheostomy has the advantages of reduced surgical trauma, shorter operation time, and fewer complications [5].

Despite the overall low incidence of tracheostomy-related complications, serious side effects and death have been reported. The rate of bleeding during the operation is 31%, and the rate of airway complications is 29.6% [6]. Manara et al. [7] showed that the most severe bleeding stemmed from abnormalities in the anatomy of blood vessels. Among the tracheotomy-related bleeding cases, major bleeding caused by innominate artery injury is the most dangerous [8]. This can cause blood to enter the airway, resulting in asphyxia and hemorrhagic shock [9]. The incidence of posterior tracheal wall injuries range from 0.2–12.5% [10]. The incidence of posterior tracheal wall injury with PDT is higher than that with open surgical tracheostomy [11]. Severe injury may be accompanied by tracheoesophageal and tracheomediastinal fistulas requiring surgical treatment [12].

Recent studies have shown that ultrasonography is a potentially useful tool for assisting PDT. Preoperative ultrasonography helps identify the location and anatomical relationships of landmarks such as the thyroid gland, cricoid cartilage, and vascular system, improving the accuracy of puncture and avoiding vascular-related complications such as bleeding [13]. It can also help in correctly selecting the size and length of the tracheotomy catheter, especially in children and patients with obesity [14]. Intraoperative ultrasonography allows real-time guidance and visualization of the needle path and depth to avoid injury to the posterior tracheal wall [15]. Compared with landmark-guided PDT, real-time ultrasound-guided PDT has been shown to significantly improve the first puncture rate and reduce procedure-related complications [16]. Regarding long-term outcomes, ultrasound-guided PDT reduces the proportion of patients with post-extubation airway stenosis [17].

A meta-analysis published in 2021 compared landmark-guided PDT with ultrasound-guided PDT [18]. However, these trials were small and limited in sample size and data quality. Two new randomized controlled trials (RCTs) were published in 2022 [19, 20]. Therefore, we updated this meta-analysis to compare first-pass success, complications, major bleeding, and tracheotomy time between landmark- and ultrasound-guided PDT.

Methods

The review and analysis were performed in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines [21]. The study protocol was registered with PROSPERO (CRD42024570426).

Search strategy

We searched PubMed, Web of Science, MEDLINE, CINAHL, Cochrane Library, Wanfang Data Knowledge Service Platform, China National Knowledge Infrastructure (CNKI) and Chinese Biomedical Literature Service System (SinoMed). The search deadline was July 31, 2024. The search was performed by combining the subject words with free words. The retrieval was connected using Boolean logical operators: ("tracheostomy" OR "tracheotomy") AND ("ultrasound" OR "ultrasonography" OR "echography"). We also manually searched references for reviews and initial inclusions. There were no language restrictions in the literature.

Inclusion and exclusion criteria

Inclusion criteria for our study were: the type of study was RCT or non-RCT; the participants were intubated patients requiring tracheotomy, aged > 18 years; the surgical modalities of tracheostomy were landmark guidance and ultrasound guidance; the incidence of major bleeding and the success rate of the first puncture were the primary outcome, and the operative time of tracheotomy and the periprocedural complications were the secondary outcome. We excluded studies on pediatric patients, the use of fiberoptic bronchoscopes during tracheotomy, and surgical procedures. Research published as a conference abstract, case report, or letter was excluded.

Literature screening and data extraction

Two researchers independently screened the studies according to the inclusion and exclusion criteria. All retrieved literature was imported into NoteExpress (Beijing Tongfang Knowledge Network Technology Co., Ltd., Beijing, China) for weight reduction. Initial screening was performed by reading the titles and abstracts. After the initial screening, the full text was read to determine the final literature to be included. When the two researchers disagreed about the inclusion of literature, it was resolved through discussion or recourse with a third researcher. Two researchers used standardized data collection tables to extract the main information from the included literature, including the first author, publication date, country, study participants, sample size, age, body mass index, and outcome indicators. For missing data, we obtained the information by contacting the first or corresponding author.

Risk of bias and quality assessment

Randomized controlled trials were independently assessed for the risk of bias by two investigators using the Cochrane Manual 5.1.0-recommended RCT risk assessment tool [22]. The evaluation included random sequence generation, assignment hiding, researcher and participant blinding, outcome evaluation blinding, outcome data integrity, selective reporting of the study results, and other biases. The evaluators were asked to make a judgment of "low risk of bias," "high risk of bias," and "unclear" for each entry. The risk of publication bias was assessed using funnel plots. The Jadad scale was used to evaluate the quality of the RCT, including randomization, blinding method, and trial integrity. The Newcastle-Ottawa Quality Assessment Scale (NOS) was used to evaluate the quality of non-RCTs, which included eight items in three dimensions: selection, comparability, and outcome. A high-quality study was considered an RCT with a Jadad scale score of > 2 or a non-RCT with an NOS score of > 5. When two researchers have differences in the evaluation of the literature quality, a third researcher should negotiate to resolve these differences.

Statistical analysis

Statistical analyses were performed using Review Manager 5.4 (RevMan 5.4.1; https://revman.cochrane.org) provided by the Cochrane Collaboration (Oxford, UK). Continuous variables are represented as mean difference (MD) or standard mean difference (SMD) and 95% confidence intervals (95%CI). The bicategorical variables were represented by odds ratio (OR) and 95%CI. The χ^2 test and I^2 statistics were used to determine the heterogeneity of the included studies. If $P > 0.1$ and $I^2 < 50\%$, there was no significant statistical heterogeneity between the studies, and fixed effect model was selected for analysis. If $P \leq 0.1$ and $I^2 \geq 50\%$, there was significant heterogeneity between the studies, and a random effects model was used. Sensitivity analysis was conducted by sequentially removing individual studies to examine their influence on the pooled results. Descriptive analysis was performed if the heterogeneity was too obvious. $P < 0.05$ was considered statistically significant.

Results

Results of the literature search

Overall, 441 studies were identified by searching the databases. After removing the duplicates, 136 studies were selected for detailed evaluation. Thirteen studies were selected after reading the titles and abstracts and their full texts were retrieved. After reading the full text, six studies, including five RCTs [19, 20, 23–25] and one non-RCT [26], were included in the meta-analysis. The literature screening process is presented in Supplementary File 1.

Basic characteristics and quality of the included literature

The features of the included studies are summarized in Table 1. A total of 609 patients requiring tracheotomy were included, of whom 308 underwent

Table 1 Characteristics of included studies

Study	Country	Study design	Population	Number of patients		Average age		BMI		Quality assessment
				Landmark	Ultrasound	Landmark	Ultrasound	Landmark	Ultrasound	
Dinh2014[26]	USA	non-RCT	ICU Patients	12	11	50 ± 21	56 ± 18	26.7 ± 7.1	28.0 ± 5.7	8
Dugg2022[19]	India	RCT	ICU Patients	50	50	48.32 ± 18.43	49.06 ± 14.54	25.80 ± 4.34	25.83 ± 5.27	3
Kumar2022[20]	India	RCT	Critically ill patients	28	30	NA	NA	23.07 ± 2.58	22.96 ± 2.45	3
Kupeli2017[23]	Turkey	RCT	ICU Patients	20	Long axis:20 Short axis:20	71.0 ± 12.5	Long axis: 64.2 ± 17.4 Short axis: 69.0 ± 16.3	28.8 ± 4.5	Long axis: 26.3 ± 3.7 Short axis:28.6 ± 4.4	2
Rudas2014[24]	Australia	RCT	ICU Patients	24	23	58.4 ± 15.2	57.0 ± 15.1	30.3 ± 8.4	26.1 ± 7.2	4
Yavuz2014[25]	Turkey	RCT	ICU Patients	167	154	57.5 ± 11.3	59.6 ± 14.9	NA	NA	2

Note: RCT: Randomized controlled trial; non-RCT: Nonrandomized controlled study; ICU: Intensive care unit; BMI: Body mass index

Table 2 Jadad score assessment of RCTs and Newcastle-Ottawa quality assessment scale of non-RCT

Newcastle-Ottawa Quality Assessment Scale of non-RCT									
Study ID	Selection				Comparability	Outcome			Total (9*)
	Representativeness of the exposed cohort (*)	Selection of non-exposed cohort (*)	Ascertainment of exposure (*)	Demonstration that outcome of interest was not present at start of study (*)	Comparability of cohorts (**)	Assessment of outcome (*)	Length of follow up(*)	Adequacy of follow up (*)	
Dinh 2014 [26]	*	*	*	*	*	*	*	*	8*

Jadad score assessment of RCTs					
Study ID	Randomization		Blinding	Withdrawals and dropouts	Total(5*)
		Appropriate method mentioned	Appropriate method mentioned		
Dugg2022 [19]	*	*		*	
Kumar 2022 [20]	*	*		*	
Kupeli 2017 [23]	*			*	
Rudas 2014 [24]	*	*	*	*	
Yavuz 2014 [25]	*			*	

Note: RCT: Randomized controlled trial; non-RCT: Nonrandomized controlled study

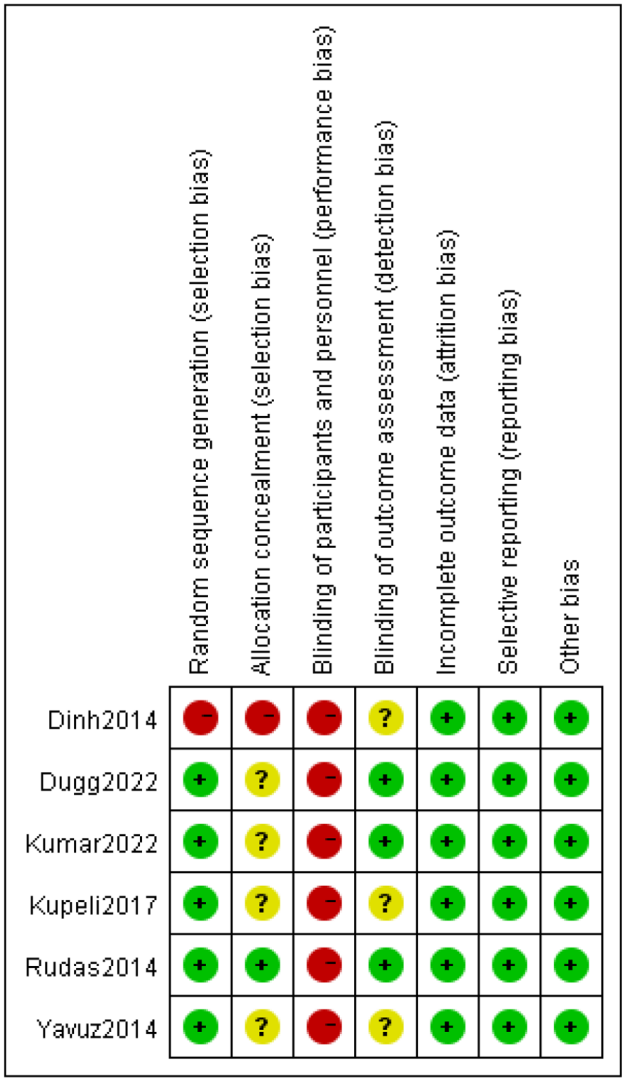

Fig. 1 Risks of bias summary

ultrasound-guided PDT and 301 underwent landmark-guided PDT. The sample size of each study ranged from 23 to 321. The ultrasound-guided PDTs included in six studies were performed under real-time ultrasound guidance. One study [23] used three percutaneous tracheotomy procedures: long-axis ultrasound, short-axis ultrasound, and anatomical markers. The incidence of major bleeding and perioperative complications was reported in all six studies. Five studies [19, 20, 23, 25, 26] reported the tracheotomy procedure times and first puncture success rates. The included RCTs had Jadad scores between 2 and 4. Rudas [24] described the implementation of randomization and blinding methods. The other four studies [19, 20, 23, 25] only mentioned randomization and did not describe its implementation in detail. Dinh's study [26] had an NOS score of 8, and control for confounding factors was not reported in the article. The quality assessment results of all the included studies are shown in Table 2.

Risk of bias assessment

The risk of selection bias was low in the included studies, except for one non-RCT study [26] that did not undergo randomization and had a high risk of selection bias. Owing to the particularity of clinical interventions, not all studies can completely blind the implementer and study participant. Most studies did not describe a blinded method for evaluating the outcomes. Data from all the included studies were reported completely, and the risk of reporting bias was low. The risk of bias for the included studies is shown in Fig. 1.

Outcome analysis

Major bleeding

All included studies [19, 20, 23–26] reported outcome measures for major bleeding. There were 5 cases (1.6%)

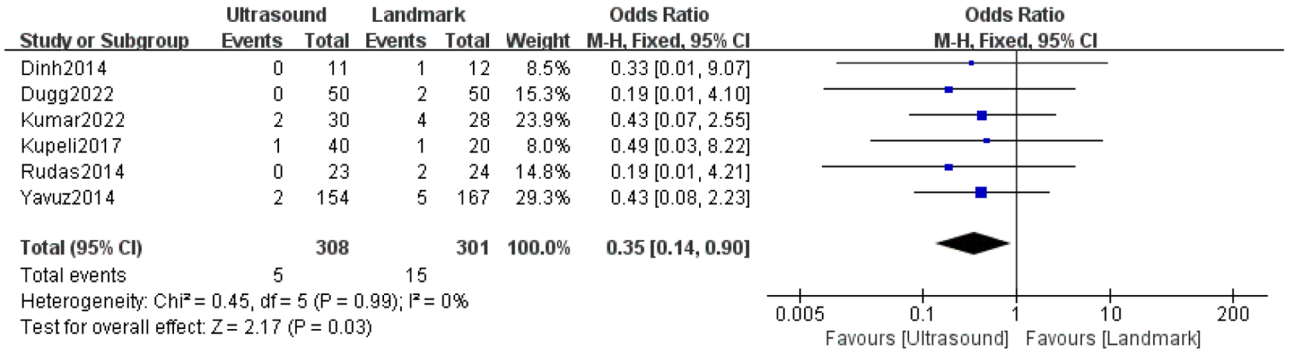

Fig. 2 Forest plot comparing ultrasound-guided PDT and landmark-guided PDT for major bleeding

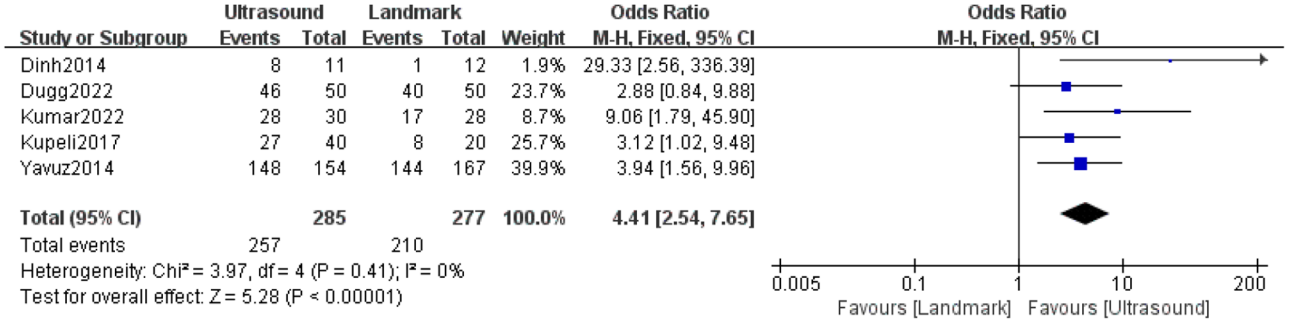

Fig. 3 Forest plot comparing ultrasound-guided PDT with landmark-guided PDT for first puncture success rate

in the ultrasound-guided PDT group and 15 (4.9%) in the landmark-guided PDT group. There was no significant heterogeneity among the included studies ($P = 0.99$, $I^2 = 0\%$). The results showed a significant difference in the incidence of major bleeding between ultrasound- and landmark-guided PDT (OR = 0.35, 95%CI [0.14, 0.90], $P = 0.03$), as shown in Fig. 2.

First puncture success rate

Five studies [19, 20, 23, 25, 26] reported first puncture success rates. The success rates of first puncture were 90.2% in ultrasound-guided PDT group and 75.8% in landmark-guided PDT groups. There was no significant heterogeneity among the included studies ($P = 0.41$, $I^2 = 0\%$). The results showed a significant difference in first puncture success rate between ultrasound PDT compared to landmark-guided PDT (OR = 4.41, 95%CI [2.54, 7.65], $P < 0.000001$), as shown in Fig. 3.

Tracheotomy procedure time

Five studies [19, 20, 23, 25, 26] reported the tracheotomy procedure time. There was heterogeneity among the included studies owing to differences in the method of calculating procedure time ($P < 0.00001$; $I^2 = 95\%$). The sensitivity analysis was conducted by excluding the study with the largest weight, Kupeli [23], and the effect size did not change significantly (MD = -0.80, 95% CI [-6.87, 5.28], $P = 0.80$). This statistical result was consistent with the overall meta-analysis results, suggesting that the results were stable. The results showed that there was no significant difference in tracheotomy procedure time between ultrasound-guided PDT and landmark-guided PDT (MD = −0.64, 95%CI [−4.14, 2.85], $P = 0.72$), as shown in Fig. 4.

Periprocedural complications

All included studies reported periprocedural complications, which occurred in 41 patients (13.3%) in the ultrasound-guided PDT group and 80 patients (26.6%) in the landmark-guided PDT group. There was no significant heterogeneity among the included studies ($P = 0.75$, $I^2 = 0\%$). The results showed a significant difference in complication rates between ultrasound-guided PDT and landmark-marker guided PDT (OR = 0.35, 95%CI [0.22, 0.54], $P < 0.00001$), as shown in Fig. 5.

Sensitivity analysis

We performed sensitivity analyses by systematically excluding each included study in sequence to evaluate the consistency of all outcome measures. The findings remained robust across these analyses, demonstrating stability of the pooled effect estimates that was concordant with the primary meta-analysis results.

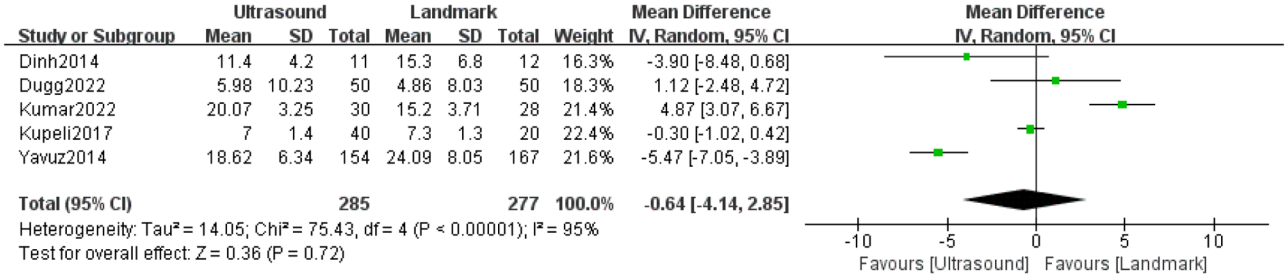

Fig. 4 Forest plot comparing ultrasound-guided PDT with landmark-guided PDT for tracheotomy procedure time

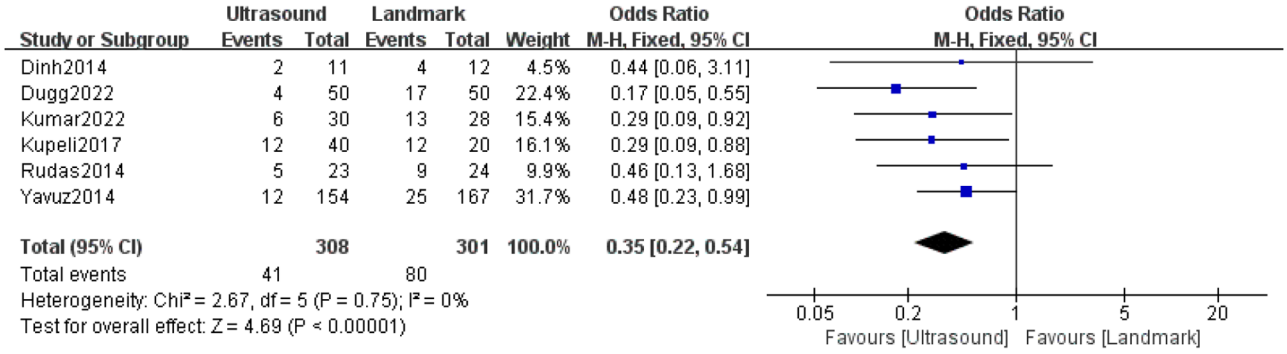

Fig. 5 Forest plot comparing ultrasound-guided PDT with landmark-guided PDT for periprocedural complications

Discussion

Our meta-analysis compared the rates of major bleeding, first puncture success rate, tracheotomy procedure time, and perioperative complications between ultrasound-guided PDT and landmark-guided PDT. Ultrasound-guided PDT reduces the incidence of major bleeding, increases the success rate of the first puncture, and reduces perioperative complications. However, the advantages of ultrasound-guided PDT over landmark-guided PDT in reducing procedure time remain unclear.

In Dugg's study [19], the incidence of major bleeding requiring intervention was higher with landmark-guided PDT (4%) than with ultrasound-guided PDT (0%). Our meta-analysis showed that ultrasound-guided PDT reduced the risk of major surgical bleeding compared to landmark-guided PDT, which is inconsistent with previous meta-analysis results [18]. There is a risk of death when major bleeding requires surgical intervention, with an incidence of 0.17% [27]. Ultrasonography can clearly visualize the structures of the neck, including the trachea, blood vessels, thyroid gland, and other key anatomical parts [28]. The distance between the skin and the anterior tracheal wall should be accurately determined. Vascular injury due to excessive depth or shallowness is avoided by choosing an appropriate puncture point and depth. Performing the puncture under real-time ultrasound guidance can clearly show the position of the tip of the puncture needle [14]. This ensures that the puncture needle accurately enters the tracheal lumen, avoiding accidental injury to the blood vessels and reducing the risk of major bleeding.

In Rudas' study [24], the first puncture success rates were 87% in the ultrasound-guided PDT group and 58% in the landmark-guided PDT group. Kupeli [23] observed that ultrasound guidance reduced the number of puncture attempts; however, advanced age significantly reduced the success rate. In addition, as the success rate of the first puncture increased, the complication rate decreased. In our meta-analysis, ultrasonography improved the first-puncture success rate of percutaneous tracheotomies. Anatomical position markings may be affected by the patient physique, skin laxity, and other factors, resulting in less precise positioning [29]. In patients with anatomical abnormalities or obesity, ultrasound can penetrate the skin and fat layers to directly show the position of the trachea, regardless of individual differences [30]. With the precise positioning of the ultrasound, the physician can accurately deliver the puncture needle into the trachea on the first attempt, thus reducing the number of unnecessary attempts and potential injuries [31]. Rajajee [32] demonstrated that real-time ultrasound guidance could help identify more appropriate tracheal puncture sites.

In Yavuz's study [25], perioperative complications occurred in 12 cases (7.8%) in the ultrasound group compared to 25 cases (15.0%) in landmark-guided group. In the landmark-guided group, 3 (1.8%) patients developed cuff perforation, 4 (2.4%) patients developed transient

oxygen desaturation, and 2 of 5 patients with major bleeding required electrocauterization followed by blood transfusions. In our meta-analysis, ultrasonography reduced perioperative percutaneous tracheostomy complications; however, data on long-term complications were missing. Ultrasound technology can monitor the surgical process in real time, which helps adjust the surgical plan in time during the operation and reduces complications caused by improper operation.

In our meta-analysis, the benefits of ultrasound-guided PDT versus landmark-guided PDT in reducing procedure time were unclear. There was significant heterogeneity among the included studies owing to differences in the calculation of surgical operation time for each study. Yavuz [25] recorded the time from the preoperative ultrasound evaluation or physical examination to the completion of tracheostomy tube placement. Kupeli [23] recorded the time from the first puncture to the completion of the tracheostomy tube placement. In Kumar's study [20], the procedure time was longer in the ultrasound-guided group than in the landmark-guided group. This is because ultrasonography performed by younger physicians requires a higher learning curve to reach proficiency levels. Therefore, more evidence is needed to explain the role of ultrasound in reducing the tracheotomy procedure time.

This meta-analysis has some limitations. First, although we included more articles than in the previous meta-analysis, the overall number of included articles and patients was still too small, reducing the reliability of our study. Second, although we aimed to include as many relevant studies as possible, the small number of studies precludes a reliable assessment of publication bias using funnel plots, as recommended by the Cochrane guidelines. Therefore, we acknowledge the potential risk of publication bias in our study, which may have influenced the results. Third, there was significant heterogeneity in the evaluation of the tracheotomy procedure time, which affected the stability of the analytical results. Finally, there was a lack of uniform standardization of training in the use of ultrasound in each study; therefore, differences in outcome metrics may be due to operator variation.

Conclusion

This meta-analysis showed that ultrasound-guided PDT reduced the incidence of major bleeding, improved the first puncture success rate, and reduced the rate of perioperative complications compared to landmark-guided PDT. However, the advantage of ultrasound-guided PDT in reducing the tracheotomy procedure time is unclear. Ultrasound-guided PDT is a safe and effective method for percutaneous tracheotomy and is expected to be increasingly used and promoted in medical institutions.

Abbreviations

PDT	Percutaneous dilatational tracheostomy
RCT	Randomized controlled trial
PRISMA	Preferred reporting Items for systematic review and meta-analysis
NOS	Newcastle-ottawa quality assessment scale
OR	Odds ratio
CI	Confidence interval
MD	Mean difference

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12871-025-03085-z.

Supplementary Material 1

Supplementary Material 2

Acknowledgements

We would like to thank all the authors involved in this study.

Author contributions

DAN WEN, XIURU YANG, and ZHENGHUA LIANG designed the study. YANG HU and DAN ZHANG collected and interpreted the data. XIURU YANG, SIMEI WANG, and YANG HU analyzed the data. YAO WANG and YUQI SHEN drafted the manuscript. DAN WEN, and XIURU YANG critically revised the paper. YUQI SHEN assists in completing the modification.

Funding

This work was supported by Sichuan Health Information Society Project [grant numbers 2024007] and Medical Quality (Evidence-Based) Management research project of Hospital Management Research Institute, National Health Commission [grant numbers YLZLXZ24G037].

Data availability

Data are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

[1]Intensive Care Unit, School of Medicine, Mianyang Central Hospital, University of Electronic Science and Technology of China, No.12 Changjia Alley, Jingzhong Street, Fucheng District, Mianyang, Mianyang, Sichuan Province 621000, China

Received: 25 September 2024 / Accepted: 18 April 2025
Published online: 25 April 2025

References

1. Yu M. Tracheostomy patients on the ward: multiple benefits from a multidisciplinary team? Crit Care. 2010;14(1):109. https://doi.org/10.1186/cc8218.
2. Esteban A, Anzueto A, Alía I, Gordo F, Apezteguía C, Pálizas F, et al. How is mechanical ventilation employed in the intensive care unit? An international utilization review. Am J Respir Crit Care Med. 2000;161(5):1450–8. https://doi.org/10.1164/ajrccm.161.5.9902018.
3. Durbin CG Jr. Tracheostomy: why, when, and how? Respir Care. 2010;55(8):1056–68.

4. Ciaglia P, Firsching R, Syniec C. Elective percutaneous dilatational tracheostomy. A new simple bedside procedure; preliminary report. Chest. 1985;87(6):715–9. https://doi.org/10.1378/chest.87.6.715.
5. Lerner AD, Yarmus L. Percutaneous dilational tracheostomy. Clin Chest Med. 2018;39(1):211–22. https://doi.org/10.1016/j.ccm.2017.11.009.
6. Klotz R, Probst P, Deininger M, Klaiber U, Grummich K, Diener MK, et al. Percutaneous versus surgical strategy for tracheostomy: a systematic review and meta-analysis of perioperative and postoperative complications. Langenbecks Arch Surg. 2018;403(2):137–49. https://doi.org/10.1007/s00423-017-1648-8.
7. McCormick B, Manara AR. Mortality from percutaneous dilatational tracheostomy. A report of three cases. Anaesthesia. 2005;60(5):490–5. https://doi.org/10.1111/j.1365-2044.2005.04137.x.
8. Nijkamp J, Jaafar RBJ, Postma L, Snoeijs M, Qiu Shao SS, Tan B. Aberrant innominate artery: A possible hazard during total laryngectomy. Laryngoscope Investig Otolaryngol. 2019;4(3):307–9. https://doi.org/10.1002/lio2.263.
9. Singh N, Fung A, Cole IE. Innominate artery hemorrhage following tracheostomy. Otolaryngol Head Neck Surg. 2007;136(4 Suppl). https://doi.org/10.1016/j.otohns.2006.10.042. S68-S72.
10. Skrzypiec Ł, Rot P, Fus M, Witkowska A, Możański M, Jurkiewicz D. Early or late tracheotomy in patients after multiple organ trauma. Otolaryngol Pol. 2021;75(6):23–7. https://doi.org/10.5604/01.3001.0015.0083.
11. Khaja M, Haider A, Alapati A, Qureshi ZA, Yapor L. Percutaneous tracheostomy: a bedside procedure. Cureus. 2022;14(4):e24083. https://doi.org/10.7759/cureus.24083.
12. Fernandez-Bussy S, Mahajan B, Folch E, Caviedes I, Guerrero J, Majid A. Tracheostomy tube placement: early and late complications. J Bronchol Interv Pulmonol. 2015;22(4):357–64. https://doi.org/10.1097/LBR.0000000000000177.
13. Plata P, Gaszyński T. Ultrasound-guided percutaneous tracheostomy. Anaesthesiol Intensive Ther. 2019;51(2):126–32. https://doi.org/10.5114/ait.2019.86277.
14. Alansari M, Alotair H, Al Aseri Z, Elhoseny MA. Use of ultrasound guidance to improve the safety of percutaneous dilatational tracheostomy: a literature review. Crit Care. 2015;19(1):229. https://doi.org/10.1186/s13054-015-0942-5.
15. Arora P, Arora R, Karim HMR, Neema PK, Panda CK. Transillumination and point-of-care ultrasonography to delineate tracheal deviation for challenging tracheostomy: a case report. Cureus. 2023;15(4):e37164. https://doi.org/10.7759/cureus.37164.
16. Iftikhar IH, Teng S, Schimmel M, Duran C, Sardi A, Islam S. A network comparative meta-analysis of percutaneous dilatational tracheostomies using anatomic landmarks, bronchoscopic, and ultrasound guidance versus open surgical tracheostomy. Lung. 2019;197(3):267–75. https://doi.org/10.1007/s00408-019-00230-7.
17. Chacko J, Gagan B, Kumar U, Mundlapudi B. Real-time ultrasound guided percutaneous dilatational tracheostomy with and without bronchoscopic control: an observational study. Minerva Anestesiol. 2015;81(2):166–74.
18. Lin KT, Kao YS, Chiu CW, Lin CH, Chou CC, Hsieh PY, et al. Comparative effectiveness of ultrasound-guided and anatomic landmark percutaneous dilatational tracheostomy: A systematic review and meta-analysis. PLoS ONE. 2021;16(10):e0258972. https://doi.org/10.1371/journal.pone.0258972.
19. Dugg K, Kathuria S, Gupta S, Gautam PL, Singh T, Bansal H. Comparison of landmark guided and ultrasound guided percutaneous dilatational tracheostomy: efficiency, efficacy and accuracy in critically ill patients. J Anaesthesiol Clin Pharmacol. 2022;38(2):281–7. https://doi.org/10.4103/joacp.JOACP_336_20.
20. Kumar P, Kumar S, Hussain M, Singh R, Ahmed W, Anand R. Comparison of percutaneous tracheostomy methods in ICU patients: conventional anatomical landmark method versus ultrasonography method - A randomised controlled trial. Indian J Anaesth. 2022;66(Suppl 4):S207–12. https://doi.org/10.4103/ija.ija_41_22.
21. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. BMJ. 2009;339:b2535. https://doi.org/10.1136/bmj.b2535.
22. Higgins JP, Altman DG, Gøtzsche PC, Jüni P, Moher D, Oxman AD, et al. The Cochrane collaboration's tool for assessing risk of bias in randomised trials. BMJ. 2011;343:d5928. https://doi.org/10.1136/bmj.d5928.
23. 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(6):533–8. https://doi.org/10.1016/j.accpm.2017.11.011.
24. 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 randomised controlled trial. Crit Care. 2014;18(5):514. https://doi.org/10.1186/s13054-014-0514-0.
25. Yavuz A, Yılmaz M, Göya C, Alimoglu E, Kabaalioglu A. Advantages of US in percutaneous dilatational tracheostomy: randomized controlled trial and review of the literature. Radiology. 2014;273(3):927–36. https://doi.org/10.1148/radiol.14140088.
26. 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(8):1407–15. https://doi.org/10.7863/ultra.33.8.1407.
27. 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(5):R258. https://doi.org/10.1186/cc13085.
28. Kim SY, Lee SW, Baek A, Park KN. Comparison between real-time ultrasound-guided percutaneous dilatational tracheostomy and surgical tracheostomy in critically ill patients: a randomized controlled trial. Clin Exp Otorhinolaryngol. 2023;16(4):388–94. https://doi.org/10.21053/ceo.2023.01088.
29. 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(5):1061–9. https://doi.org/10.1002/jum.14448.
30. 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(2):158–64. https://doi.org/10.1016/j.mjafi.2015.01.013.
31. 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(3):342–51. https://doi.org/10.1007/s00134-016-4218-6.
32. 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(1):198. https://doi.org/10.1186/s13054-015-0924-7.

Publisher's note