Safety and efficacy of ultrasonography before and during percutaneous dilatational tracheostomy in adult patients: a systematic review

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ABSTRACT

Objective: A systematic review to examine the safety and efficacy of ultrasound before and/or during percutaneous dilatational tracheostomy (PDT).

Methods: Systematic searches of MEDLINE, PubMed, EMBASE, and the Cochrane Central Register of Controlled Trials were undertaken to identify trials reporting on safety and efficacy of using ultrasound guidance before and/or during PDT.

Results: Ultrasound before PDT: no controlled trials; two observational studies suggested a possible benefit in avoiding serious complications by identifying vulnerable vascular structures. Real-time ultrasound during PDT: one controlled study, which retrospectively compared real-time ultrasound guidance with the landmark-guided technique and found it to be superior in avoiding cranial misplacement; it appeared to be safe and effective in two observational studies.

Conclusions: There are currently no randomised controlled trials to establish the safety or efficacy of preprocedural and/or real-time intraprocedural ultrasound guidance during PDT compared with the current standard of care. One study supports the use of real-time ultrasound guidance during PDT in preventing cranial tracheostomy tube misplacement. Observational data suggest that preprocedural ultrasound may help prevent vascular complications and that real-time ultrasound guidance during PDT is likely safe, with a high success rate. A prospective randomised controlled trial evaluating its safety and efficacy compared with the traditional landmark-guided technique is required to establish its role in clinical practice.

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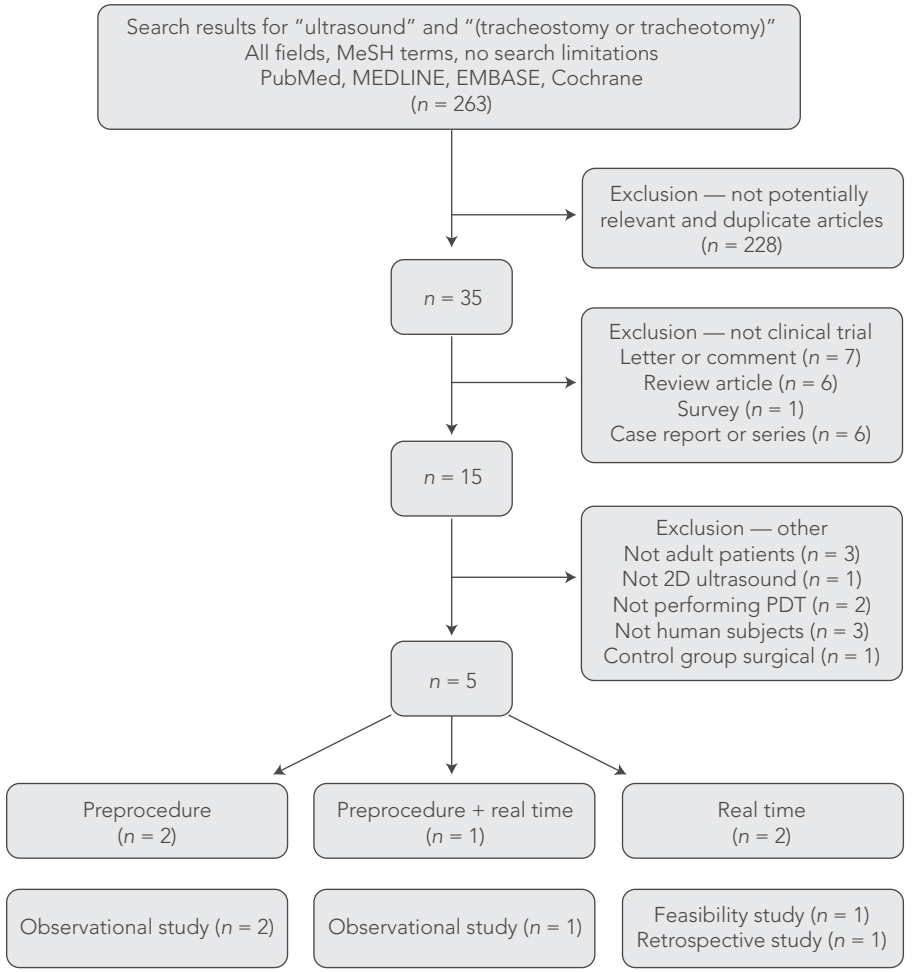
Patients in intensive care frequently receive tracheostomy for long-term ventilator support. Percutaneous dilatational tracheostomy (PDT) has established advantages and is the preferred method over surgical tracheostomy (ST),[1] which is now reserved for select cases. Although overall complication rates are low, PDT remains one of the few procedures routinely undertaken in intensive care where serious adverse events including death are still reported. Most serious bleeding complications relate to unrecognised and unanticipated anatomical variation in vasculature in the immediate periprocedural setting[2,3] or to tracheal tube erosion into adjacent vasculature in the case of late bleeding complications, which are thought in turn to be related to initial tracheal tube malposition.[4,5] Bronchoscopic guidance during the procedure has been widely used as an additional safety adjunct and with the increasingly wide availability of bedside ultrasonography in the intensive care setting, preprocedural and real-time intraprocedural ultrasound guidance has also been advocated as a potential tool to further improve safety and efficacy of the procedure.[6-8]

It is common for patients receiving a tracheostomy to have anatomy that is considered difficult. This is most often due to obesity, or anatomical deformity from chronic musculoskeletal pathology or prior injuries and surgical procedures, making palpation of the traditionally used anatomical features difficult or even impossible. The difficulties encountered in locating landmarks such as the cricothyroid membrane and difficulties with tracheal puncture when the tracheal anatomy is not readily palpable have been highlighted by multiple recent studies both in real patients and on simulated models.[9-11] Ultrasound has been successfully used in such difficult clinical cases to guide the tracheal puncture.[12]

The theoretical advantage of using preprocedural ultrasound lies with the ability to identify aberrant pretracheal vasculature in order to avoid immediate vascular complications[6] and it may also aid in proper selection of tracheostomy tube size and length, especially in patients with an increased pretracheal soft tissue diameter or in children.[13] Real-time intraprocedural ultrasound may assist not only with identifying the tracheal anatomy and potentially aberrant vessels but also with identifying the preferred puncture location and guiding the needle puncture of the trachea, not dissimilar to the technique routinely used in ultrasound-guided vascular access.

Ultrasonographic anatomy of the anterior neck with consideration to the implications for tracheostomy was first described in 1995[14] and a report of real-time ultrasound-guided puncture for percutaneous tracheostomy was first published in 1999.[15]

Figure 1. Systematic review examining the safety and efficacy of ultrasound before and/or during percutaneous dilatational tracheostomy (PDT)



Cochrane = Cochrane Central Register for Controlled Trials. MeSH = Medical Subject Headings.
2D = two-dimensional.

With an increasing number of reports on the use and potential benefits of ultrasound, especially in patients with difficult cervical anatomy,[12] as well as recent inclusion into practice guidelines,[16] a systematic review was performed in order to evaluate the available literature and to perform a meta-analysis comparing safety and efficacy of ultrasound guidance before and during PDT as compared with standard care.

Methods

Search strategy

The databases MEDLINE, PubMed, the Cochrane Central Register for Controlled Trials and EMBASE were searched using the search terms "ultrasound" and "(tracheostomy or tracheotomy)". No limitations were placed on language or date of publication. One of the authors (M R) examined each title and abstract and potentially relevant articles were reviewed in full. The reference list from all relevant articles was also reviewed and cross-checked and, if required, further articles not located previously were also assessed.

Inclusion criteria

Clinical trials evaluating the use of ultrasound either before the procedure to assess cervical anatomy or in real-time to assess cervical anatomy and guide tracheal puncture during PDT were selected for this review. Prospective trials that reported procedural safety (immediate and/or long-term complication rate) or efficacy data (number of puncture attempts, puncture time and puncture location in relation to the tracheal anatomy) in both the intervention and a control group of standard percutaneous tracheostomy patients were sought for a planned meta-analysis.

Exclusion criteria

Publications were excluded if they were not clinical trials (case reports, surveys, review articles, letters to the editor), or if they were non-human studies or studies on human cadavers. Studies on paediatric patients, studies using other than a two-dimensional modality of ultrasound (such as Doppler) and studies where the control group received surgical tracheostomy were also excluded.

Results

The search strategy identified 263 publications (Figure 1). After review of the abstracts, 228 papers were excluded as not relevant. A further 20 publications with relevant content were found not to be clinical trials. Of the remaining 15 studies, three were not conducted on adult patients, two did not actually perform a tracheostomy, three were not done on human subjects, one study did not use two-dimensional ultrasound and one study compared the percutaneous puncture to the surgical technique, leaving five

Table 1. Studies of percutaneous dilatational tracheostomy (PDT)

Author	Study type	Setting	No. of patients	Intervention	Control	PDT method	Results
Bonde J et al[17]	Prospective observational	Intensive care	28	Preprocedural ultrasound	None	Griggs 100%	Changed puncture location in nine patients (32.1%); elective vessel ligation in three patients (10.7%); minor periprocedural bleeding in two patients (7.1%)
Kollig E et al[18]	Prospective observational	Intensive care: surgical	72	Preprocedural ultrasound	None	Ciaglia 90.2%; Griggs 9.8%	Changed puncture location in 17 patients (23.6%); changed to surgical tracheostomy in one patient (1.3%); minor periprocedural bleeding in one patient (1.3%)
Sustić et al[19]	Retrospective	Intensive care: multi-disciplinary	26	Real-time ultrasound	Landmark-guided PDT	Griggs 100%	Cranial misplacement: 0% v 33% ($P < 0.05$); tracheal ring fracture: 36% v 43% (not significant)
Rajajee et al[20]	Prospective feasibility	Intensive care	13	Real-time ultrasound	None	Ciaglia 100%	All PDTs successful; positioning of puncture appropriate as confirmed on bronchoscopy; no significant periprocedural complications reported
Guinot et al[21]	Prospective observational	Intensive care	50	Preprocedural ultrasound and real-time ultrasound	None (grouped by BMI)	Ciaglia 100%	All PDTs successful; no difference in time required or complication rate in low BMI v high BMI groups; changed puncture location in 25 patients (50%); minor periprocedural bleeding in three patients (6%); wound infection in one patient (2%)

BMI = body mass index.

published studies included in this systematic review. To be able to separately assess the impact of the two different modalities of preprocedural or real-time intraprocedural ultrasound for PDT, the identified studies were divided into two groups. One study used both methods. In the preprocedural ultrasound group, no controlled trials were identified. In the real-time procedural group one retrospective, non-randomised controlled trial was included. Prospective observational studies, without control groups or historical control data, were identified in both groups. No study reported on the prespecified safety or efficacy measures and as such no meta-analysis was possible.

Preprocedural neck ultrasound examination

Two prospective observational studies were identified (Table 1). Bonde et al describe 28 consecutive patients over a study period of 1 year who underwent PDT using a Griggs guidewire dilating forceps technique.[17] Bronchoscopy was not used during the procedure. They excluded patients with severe coagulopathy, as well as those with short necks or those who were morbidly obese; a total of three patients over the study period. They report a change in the planned location of the tracheal puncture in nine of the 28 patients, mostly in an attempt to avoid puncture of the thyroid isthmus, as well as three cases of electively ligating vessels during the procedure based on ultrasound findings. Complication rates were low, with only two cases of minor bleeding reported, but no control group or historical data are available for comparison. Kollig et al reported 72 consecutive patients over a 22-month period who received a tracheostomy in an adult surgical intensive care unit.[18] All patients underwent preprocedural ultrasound evaluation of the neck followed by percutaneous tracheostomy, predominantly using the Ciaglia single-tapered dilator method under bronchoscope control. Ultrasound evaluation resulted in a change from the planned tracheal puncture site in 23.6% of patients. The reported complication rate was low, with one case of minor periprocedural bleeding, but there are no control group or historical data for comparison.

Real-time ultrasound during PDT

One retrospective controlled study was identified (Table 1). Sustić et al retrospectively examined the en-bloc resected tracheas of 26 consecutive intensive care patients who underwent PDT but later died.[19] Fifteen patients had conventional landmark-guided PDT and in 11 patients, PDT was carried out using real-time ultrasound guidance, the indication for which was a not clearly palpable cricoid or otherwise challenging anatomy. The operator was the same for all 26 patients. Five patients (33%) in the landmark group had cranially displaced tracheostomy tubes — defined as being between the cricoid cartilage and the first tracheal ring — whereas no patient was found to have cranial

displacement in the real-time ultrasound group ($P < 0.05$). Fractured tracheal rings were found in 43% v 36% of patients in the two groups, respectively. In a prospective feasibility study, Rajajee et al demonstrated that real-time ultrasound guidance was used to appropriately position the tracheal puncture as confirmed by bronchoscopy in 13 patients.[20] The authors observed no significant periprocedural complication. No control group or historical data were presented for comparison.

Preprocedural plus real-time ultrasound during PDT

Guinot et al prospectively evaluated the implications of obesity in ultrasound-guided tracheostomy in intensive care patients (Table 1).[21] Over an 18-month period, 50 consecutive patients who underwent the procedure were assessed in two groups based on body mass index (median, 34 kg/m^2 v 25 kg/m^2; $P < 0.001$). The investigators used both pre-procedure and real-time intraprocedural ultrasound. There was no difference in time required to perform the tracheostomy or complication rates, which involved only minor complications and were low in both groups. However, patients with a platelet count below 80 000/mm^3 or an international normalised ratio above 1.2 were excluded. The location of the tracheal puncture, as compared with that determined by landmark technique before ultrasound examination, was changed based on the ultrasound findings in 50% of patients; this was due to aberrant vasculature in 32%.[21]

Discussion

Ultrasound guidance, either periprocedurally or real-time, has been proposed as an additional safety and efficacy measure for PDT and receives mention in the recently published Australian New Zealand Intensive Care Society consensus statement.[16]

However, the data supporting this modality at the time of this review are far from robust. The available studies are all small and largely observational in nature. Only one study included a control group. Most studies had a single or only a small number of operators, and recruitment was often biased by operator availability. Only three of the studies used the Ciaglia method for performing the PDTs; other studies examined the Griggs method. Most studies reported a low periprocedural complication rate but presented no control group or historical control data for comparison. Interestingly, in the three studies that did report on this, the percentage of cases where the intended puncture site was changed based on ultrasound findings was quite high (23.6%, 32.1% and 50%, respectively). However, whether this translates into an actual decrease in complications is uncertain without a control group. No study with a control group carried out any long-term follow-up. Therefore, the postulated benefit of real-time ultrasound in avoiding low tracheal puncture, which in turn can result in late bleeding complications, is unclear. Also, no study examined the potential relationship between ultrasound-guided positioning of the tracheostomy tube and late complications such as tracheal stenosis. It should also be noted that significant complications either during or in the intermediate to long term following tracheostomy are relatively rare; a large sample size would therefore be required to detect a beneficial effect.

Despite the lack of good-quality evidence, the small number of available case reports and studies appear to suggest that the method is safe, reliable and offers a potential benefit over the traditional landmark-guided procedure, especially in select patient groups such as those who are obese or have difficult-to-palpate or unconventional cervical anatomy.

This systematic examination of the literature supporting ultrasound use before or during PDT in adult intensive care patients highlights the fact that, to date, there are no prospective, randomised controlled studies with a clinically relevant comparator group. To establish the role of this modality in clinical practice, a prospective randomised controlled trial demonstrating its safety and efficacy and evaluating its potential benefit compared with the traditional landmark-guided technique is required.

Competing interests

None declared.

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