The role of ultrasound in percutaneous dilatational tracheostomy

Abstract

**Background:** The use of ultrasound to evaluate cervical anatomy and to guide tracheal puncture in real-time has been advocated to improve safety and efficacy of percutaneous dilatational tracheostomy (PDT) in intensive care.

**Objective:** To review the potential role, attributed theoretical benefits and supporting literature for ultrasound during PDT.

**Results:** A significant number of mostly observational studies and case series support this modality. Real-time guidance enables clear visualisation of anatomical landmarks and results in a consistently high success and low complication rate, with appropriate positioning of the tracheal puncture. Recognition of unconventional vascular anatomy enables selection of an appropriate alternative puncture site or an elective open surgical approach.

**Conclusion:** Current literature supports that using ultrasound for percutaneous tracheostomy is quick, safe, reliable and offers a plausible advantage over the traditional landmark guided procedure, especially in select patient groups, such as those who are morbidly obese or have difficult to palpate cervical anatomy.

**Keywords:** dilatational, percutaneous, tracheostomy, trachea.
most often due to morbid obesity or anatomical deformity from chronic musculoskeletal pathology or prior injuries and surgical procedures. This can make palpation of the traditionally used anatomical features difficult or even impossible.\textsuperscript{12–14} This in turn can lead to an increase in the rate of procedural complications, failed and multiple puncture attempts. Suboptimal position of the tracheal puncture can subsequently lead to tracheostomy tube malposition. The difficulties encountered in locating anatomical landmarks such as the crico-thyroid membrane and difficulties with tracheal puncture when the tracheal anatomy is not readily palpable have been highlighted by recent publications.\textsuperscript{15} Ultrasound in such a setting performs well in a simulated environment\textsuperscript{16,17} and has been demonstrated to be useful in clinical practice.\textsuperscript{18}

**Ultrasound use in percutaneous dilatational tracheostomy**

The theoretical advantage of using pre-procedural ultrasound lies with the ability to identify relevant cervical anatomy and aberrant pre-tracheal vasculature in order to avoid immediate vascular complications.\textsuperscript{19} It may also aid in proper selection of tracheostomy tube size and length, especially in patients with an increased pre-tracheal soft tissue diameter or in children.\textsuperscript{20} Intraprocedural (i.e. real-time) ultrasound may assist not only by revealing potentially aberrant vessels\textsuperscript{21} but also with identifying the preferred puncture location and guiding the needle puncture of the trachea. The technique is not dissimilar to that routinely used during ultrasound guided vascular access.

Ultrasonographic anatomy of the anterior neck with consideration to the implications for tracheostomy was first described in 1995\textsuperscript{22} and a report of real-time ultrasound guided puncture for percutaneous tracheostomy was first published in 1999.\textsuperscript{23} 2D ultrasound using a linear array probe readily identifies the position and anatomical relation of all important landmarks. These include the thyroid and cricoid cartilage, the tracheal rings, the thyroid gland and the carotid and jugular vessels. Aberrant vascular structures crossing the midline should be noted and can
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Further be evaluated by colour or spectral Doppler. Real-time imaging can be used to identify the desired level of puncture in a sagittal plane in the midline over the trachea, while a ninety-degree rotation of the probe allows for an out-of-plane approach to guiding the needle tip (represented by an acoustic shadow) towards the midline. Results using this technique have been described by Chacko, et al.24

Pre-procedural ultrasound examination of the neck

The utility of pre-procedural scanning of the neck has been investigated by a number of authors. Bonde, et al. describe 28 consecutive patients over a study period of one year who underwent PDT.25 The authors 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.

Figure 3a and 3b:
Actual longitudinal (A) and transverse (B) views obtained with a linear probe during bedside percutaneous tracheostomy.
as well as three cases of electively ligating vessels during the procedure based on ultrasound findings. Complication rate is low with only two cases of minor bleeding reported. Patients with severe coagulopathy as well as those with short necks or those who were morbidly obese were excluded. Kollig, et al. reported 72 consecutive patients requiring PDT over a 22 month period.26

All patients underwent pre-procedure ultrasound evaluation of the neck followed by percutaneous tracheostomy, with bronchoscopic control. Ultrasound findings resulted in a change from the planned tracheal puncture site in 23.6% of patients. The reported complication rate is low with only one case of minor peri-procedural bleeding in the group.

Real-time ultrasound guidance for tracheal puncture during percutaneous tracheostomy
Šustić, et al. retrospectively examined the en-bloc resected tracheas of twenty-six consecutive intensive care patients who underwent PDT but later died.27 Fifteen patients had conventional landmark guided PDT and in 11 patients PDT was carried out using real-time ultrasound guidance. The indication for using ultrasound was a not clearly palpable cricoid or otherwise challenging anatomy. 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 misplacement in the real-time ultrasound group ($P < 0.05$). Fractured tracheal rings were
found in 43% vs. 36% of patients in the two groups respectively ($P = \text{NS}$). The same authors have also published their results from a 26-month period where they randomly assigned adult intensive care patients who had acute cervical cord injury with subsequent anterior cervical spinal fusion and required tracheostomy, to either surgical tracheostomy (ST) or real-time ultrasound guided PDT.\(^{29}\) Complication rate was low with one case of minor peri-procedural bleeding in each group. Two cases of wound infection were noted in the surgical group, no infections occurred with PDT. The average time required for performing the procedure was eight vs. 21 minutes ($P < 0.05$) in the PDT and ST groups respectively. Recently Rajajee, et al. demonstrated that real-time ultrasound guidance was used to appropriately position the tracheal puncture as confirmed by bronchoscopy in thirteen patients.\(^{29}\) The authors observed no significant peri-procedural complication. Their results are mirrored by the findings of Chacko, et al. in a larger series of 62 patients.\(^{24}\) In another recent publication Guinot, et al. prospectively evaluated the implications of obesity in ultrasound guided tracheostomy in intensive care patients.\(^{30}\) Over an 18-month period, 50 consecutive patients who underwent the procedure were assessed in two groups based on body mass index (BMI). Median BMI was 34 vs. 25, ($P < 0.001$) respectively. The investigators utilised both pre-procedure and real-time intra procedure ultrasound. There was no difference in time required to perform the tracheostomy or complication rate, which involved only minor complications and was low in both groups. Patients with platelet counts below 80.000/mm-3 or INR above 1.2 were however excluded. Notably, the authors report that the location of the tracheal puncture, as compared to that determined by landmark technique prior to ultrasound examination, was changed based on the ultrasound findings in 50% of patients, and that this was due to aberrant vasculature in 32%.  

**Discussion**

Ultrasound guidance, either peri-procedurally or real-time, has been proposed as an additional measure to improve safety and efficacy of percutaneous dilatational tracheostomy and receives mention in the recently published ANZICS Percutaneous Dilatational Tracheostomy Consensus Statement.\(^{31}\)

Although to date no study has compared pre- or intra-procedural ultrasound guidance to the traditional landmark approach in a prospective randomised controlled fashion, a significant number of observational studies and case series appear to support the utility of this modality. Publications consistently report a low peri-procedural complication and high success rate, which is on par or better than historical data. Plausible advantage arises from being able to avoid aberrant vascular structures and from easy visual localisation of important anatomical landmarks, which may at times be impossible to locate by palpation. 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. This implies that a large number of conventional tracheal punctures may not be performed at the perceived ideal anatomical location, though this may not translate directly to a similarly striking difference in complication rates. On the other hand, many of the postulated benefits relating to appropriate positioning of the tracheostomy tube relate to avoidance of mid to long-term complications. As no study has undertaken long-term follow-up, the extent of this potential benefit cannot be adequately assessed based on current literature. It should also be noted that significant complications both immediate and longer term are relatively rare, therefore a large sample size would be required to detect and demonstrate a statistically significant effect.  

**Conclusion**

Despite the lack of high quality supporting evidence, overall available data appear to suggest that using ultrasound for percutaneous tracheostomy is quick, safe, reliable and offers a plausible advantage over the traditional landmark guided procedure, especially in select patient groups. These include the morbidly obese and those who have difficult to palpate or unconventional cervical anatomy. A randomised controlled trial comparing the use of ultrasound to a traditional landmark guided approach during PDT would be required to provide more definitive information on the role and degree of potential benefit offered by adopting this modality in routine day-to-day intensive care practice.
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