Traditional landmark versus ultrasound guided tracheal puncture during percutaneous dilatational tracheostomy in adult intensive care patients: a randomised controlled trial

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Traditional landmark versus ultrasound guided tracheal puncture during percutaneous dilatational tracheostomy in adult intensive care patients: a randomised controlled trial

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Abstract

Introduction

Long-term ventilated intensive care patients frequently require tracheostomy. Although overall risks are low, serious immediate and late complications still arise. Real-time ultrasound guidance has been proposed to decrease complications and improve accuracy of the tracheal puncture. We aimed to compare procedural safety and efficacy of real-time ultrasound guidance with the traditional landmark approach during percutaneous dilatational tracheostomy (PDT).

Methods

A total of 50 patients receiving PDT for clinical indications were randomly assigned, after informed consent, to have the tracheal puncture carried out using either traditional anatomical landmarks or real-time ultrasound guidance. Puncture position was recorded via bronchoscopy. Blinded assessors determined in a standardised fashion the deviation of the puncture off midline and whether appropriate longitudinal position between the first and fourth tracheal rings has been achieved. Procedural safety and efficacy data, including complications and number of puncture attempts required, were collected.

Results

In total 47 datasets were evaluable. Real-time ultrasound guidance resulted in significantly more accurate tracheal puncture. Mean deviation from midline was 15 ± 3 versus 35 ± 5 degrees ($P = 0.001$). The proportion of appropriate punctures, defined a priori as 0 ± 30 degrees from midline was significantly higher, 20/23 (87%) versus 12/24 (50%) (RR = 1.74; 95% CI = 1.13 to 2.67; $P = 0.006$). First pass success rate was 20/23 (87%) in the ultrasound and 14/24 (58%) in the landmark group (RR = 1.49, 95% CI = 1.03 to 2.17; $P = 0.028$). The observed decrease in procedural complications was not statistically significant 5/23 (22%) versus 9/24 (37%) (RR = 0.58; 95% CI = 0.23 to 1.47; $P = 0.24$).

Conclusions

Ultrasound guidance significantly improved the rate of first-pass puncture and puncture accuracy. Fewer procedural complications were observed however this did not reach statistical significance. These results support wider general use of real-time ultrasound guidance as an additional tool to improve PDT.

Trial registration

Australia and New Zealand Clinical Trials Registry ACTRN12611000237987, registered 04 March 2011

Introduction

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 [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 significant adverse events including death are still reported [2-5]. With the increasing availability of bedside ultrasonography in the intensive care setting, pre-procedural and real-time intra-procedural ultrasound guidance has been advocated as a potential tool to further improve safety and efficacy of the procedure [6,7].

Despite an increasing number of publications in recent literature describing favorable results and advocating the use of ultrasound for PDT [8,9], there is a paucity of high quality evidence and a recent systematic review failed to identify any randomised controlled trials in support of this modality [10]. To answer the question whether using real-time ultrasound guidance improves the procedural safety and efficacy of tracheal puncture we conducted a prospective randomised controlled trial comparing this novel approach to the landmark method in adult intensive care patients requiring PDT.

Methods

Trial design

The TARGET Study was a prospective randomised controlled trial carried out at two participating sites, Royal Prince Alfred Hospital and Nepean Hospital in Sydney, Australia. The aim of the study was to compare the use of real-time ultrasound guidance to landmark guided tracheal puncture during PDT. The primary outcome measure was accuracy of tracheal puncture, defined as less than 30 degree deviation from midline and appropriate longitudinal puncture between the 1st and 4th tracheal rings. A secondary measure of efficacy was the first pass success rate. Studied measures of safety were peri-procedural and intermediate term complication rates.

Sample size

Lacking published data, an estimate of the degree of malposition was used to calculate sample size requirements. Presuming an average displacement of 25 degrees from midline in the landmark and 15 degrees in the ultrasound group with 15 and 10 degrees respective standard deviation we estimated that a sample size of 50 would be required to detect a statistically significant difference with a 0.05 confidence interval and statistical power of over 80%.

Participants and enrollment

Ethics approval was obtained for both participating sites (see Acknowledgements) and the trial registered with the Australia and New Zealand Clinical Trials Registry (ACTRN12611000237987). Adult intensive care patients, defined as being over 18 years of age at the time of enrolment, requiring a percutaneous dilatational tracheostomy for clinical reasons were eligible, with the only exclusion criterion being pregnancy. As patients were unable to consent, in accordance with the Ethics approval informed consent was obtained from the person responsible prior to study enrollment. As set out by NSW Health policy the person responsible was most commonly an enduring guardian, spouse or other close relative. Patients were randomised in a 1:1 ratio to intervention and control arms, using permuted blocks of four and six, and allocation concealment was maintained by using sequentially
numbered opaque sealed envelopes created according to published recommendations [11]. An independent member of the research team who was not directly involved with the study in any other capacity created the randomisation sequence using a computer algorithm [12] and prepared and sealed the envelopes. Once consent was obtained, patients were enrolled by selecting the topmost sequentially numbered envelope, which contained the study group allocation.

**Interventions**

Patients in both groups underwent a standard PDT using the Ciaglia single tapered dilator technique [13] using the Ciaglia Blue Rhino® kit (Cook Medical Inc., Bloomington IN, USA). Percutaneous tracheal needle puncture was followed by insertion of a guide-wire, use of the tapered dilator to create the tract and insertion of the tracheostomy tube. The study intervention was use of real-time ultrasound guidance to guide the tracheal needle puncture. A Sonosite M-Turbo portable ultrasound machine (FUJIFILM Sonosite Inc., Bothell WA, USA) or a Siemens Acuson Cypress (Siemens, Munich, Germany) portable ultrasound machine was used with 5 MHz linear transducers and sterile (Bard Access Systems, Inc. Salt Lake City UT, USA) ultrasound probe covers. A midline longitudinal probe position was used to identify the cricoid and tracheal rings in cross section thereby identifying the required level of puncture ideally between the first and fourth tracheal rings. This was followed by scanning the neck in a transverse probe position and identifying the thyroid and cricoid cartilages, tracheal rings, thyroid gland and isthmus and the carotid and jugular vessels bilaterally. If significant midline vascular structures were noted the planned puncture position was modified accordingly. Tracheal puncture was carried out using a transverse probe position and real-time out of plane technique previously described [7]. An additional movie file depicts the procedure in more detail (see Additional file 1). Printed pamphlets with normal ultrasound anatomy in the longitudinal and transverse planes and a description of the study procedure were available for reference. The control arm used palpation of anatomical landmarks to carry out the tracheal puncture, which is normal practice at the participating institutions. Mandatory bronchoscopy using Pentax EPK-1000 (Pentax Medical Company, Montvale NJ, USA) or Olympus (Olympus America Inc., USA) video bronchoscopes was carried out post guide-wire insertion to confirm intraluminal position before dilation and to document the puncture position for analysis. Bronchoscopy had to take place only after the guide-wire was inserted. Bronchoscopy during needle puncture is not considered standard practice in either of the participating units and was not permitted in the study protocol. The analogue video output from the bronchoscope tower was captured with a BlackMagic analogue to digital video converter (BlackMagic Design Pty. Ltd, Fremont CA, USA) to record the full duration of the bronchoscopy from insertion of the bronchoscope into the endotracheal tube until its removal. Video was recorded using an Apple MacBook Pro laptop computer (Apple Inc., Cupertino CA, USA) and BlackMagic video recording software (BlackMagic Design Pty. Ltd, Fremont CA, USA). Dilation of the tract and insertion of the tracheostomy tube was carried out as per normal practice in both groups. All procedures were carried out by intensive care specialists or supervised senior trainees in intensive care medicine, which is consistent with current Australian practice. All proceduralists were familiar with the landmark approach but had varying experience with the ultrasound guided technique. In order to capture a representative group of clinicians, no proceduralists were excluded as long as they were willing to learn and perform both the study and control procedures.
Data collection and outcome measures

Baseline demographics and severity of illness indicators [admission APACHE II scores and SOFA scores on the day prior to tracheostomy] were collected. (Table 1) Data collected during and immediately after the procedure included number of passes, with subsequent passes defined by the need to withdraw the needle completely from the skin and reinsert it, and immediate peri-procedural complications, defined as complications arising during the procedure or during the following one hour (Table 2). A post-insertion anteroposterior mobile chest radiograph was mandatory and any complications such as pneumothorax were noted. Video acquired during bronchoscopy was recorded as described above. Follow-up of the patients occurred until day 90 or decannulation, whichever occurred first. Time to wean from the ventilator, ICU length of stay and time to decannulation was recorded. Any tracheostomy related adverse events during the follow-up period were documented. (Table 2)

Table 1 Baseline characteristics

| Characteristic [mean (SD) or number (%)] | Landmark n = 25 | Ultrasound n = 25 | P value |
|-----------------------------------------|-----------------|-------------------|---------|
| Age – years, mean (SD)                  | 58.4 (15.2)     | 57.0 (15.1)       | 0.748   |
| Male sex – number (percent)             | 12/25 (48%)     | 12/25 (48%)       | 1.000   |
| Weight - kg, mean (SD)                  | 87.8 (25.5)     | 75.2 (19.3)       | 0.059   |
| BMI - kg/m², mean (SD)                  | 30.3 (8.4)      | 26.1 (7.2)        | 0.080   |
| APACHE II - mean (SD)                   | 22.7 (5.6)      | 22.3 (6.6)        | 0.807   |
| Days ventilated prior to PDT, mean (SD) | 10.1 (4.5)      | 9.3 (4.7)         | 0.546   |
| SOFA score on day prior to tracheostomy-mean (SD) | 4.3 (2.2) | 3.9 (2.6)         | 0.516   |
| PaO2:FiO2 ≤ 200 – number (percent)      | 4/24 (16)       | 9/23 (39)         | 0.085   |
| INR, mean (SD)                          | 1.1 (0.1)       | 1.1 (0.2)         | 0.849   |
| APTT – seconds, mean (SD)               | 39.8 (9.9)      | 35.3 (9.0)        | 0.107   |
| Indication for tracheostomy [number (%)]|                 |                   |         |
| Respiratory failure                     | 18/25 (72)      | 16/25 (64)        | 0.544   |
| Poor neurological status                | 7/25 (28)       | 9/25 (36)         | 0.544   |

The groups were similar at baseline. BMI = Body Mass Index, INR = International Normalised Ratio, APTT = Activated Partial Thromboplastin Time.
Table 2 Follow-up, procedural and intermediate term complications

| Procedural complications [number (%)]* | Landmark n = 24 | Ultrasound n = 23** | P value |
|---------------------------------------|-----------------|---------------------|---------|
| Patients with procedural complications* | 9/24 (37)       | 5/23 (22)           | 0.237   |
| Patients with complications excluding minor bleeding* | 2/24 (8) | 2/23 (9) | 0.965 |
| Only minor bleeding / no intervention | 7/24 (29)       | 3/23 (13)           | 0.177   |
| Bleeding requiring intervention      | 2/24 (8)        | 0/23 (0)            | 0.157   |
| Pneumothorax                         | 0/24 (0)        | 0/23 (0)            | 1.000   |
| Tracheal injury                       | 0/24 (0)        | 0/23 (0)            | 1.000   |
| Oesophageal injury                    | 0/24 (0)        | 0/23 (0)            | 1.000   |
| Para tracheal placement              | 1/24 (4)        | 0/23 (0)            | 0.322   |
| Haemodynamic instability              | 1/24 (4)        | 0/23 (0)            | 0.322   |
| Desaturation                          | 1/24 (4)        | 1/23 (4)            | 0.975   |
| Ruptured ETT cuff                     | 0/24 (0)        | 1/23 (4)            | 0.302   |
| Intermediate term complications [number (%)] | Landmark n = 24 | Ultrasound n = 23** |         |
| Accidental decannulation              | 0/24 (0)        | 1/24 (4)            | 0.322   |
| Pressure ulcer                        | 0/24 (0)        | 1/24 (4)            | 0.322   |
| Bleeding                              | 0/24 (0)        | 0/24 (0)            | 1.000   |
| Soft tissue infection                 | 0/24 (0)        | 0/24 (0)            | 1.000   |
| Follow-up                             |                 |                     |         |
| Days to wean                          | 9.0             | 8.0                 | 0.448   |
| Days to decannulation                 | 19              | 24                  | 0.819   |
| ICU length of stay                    | 23              | 22                  | 0.556   |

* Patients with multiple procedural complications were counted as one in the overall procedural complication rate. ** In the ultrasound group procedural data were missing for one patient, follow-up data were available for all 24 patients.

Data analysis

The primary outcome measures of accurate cranio-caudal positioning and midline deviation of the tracheal puncture were derived from the bronchoscopic recordings by two blinded assessors with extensive clinical experience in bronchoscopy and percutaneous tracheostomy insertion. Still images showing the entire tracheal lumen and the guide-wire entering the trachea were taken from the video recordings. Images were scaled up or down to standardise the tracheal lumen size at the level of the guide-wire entry (10 cm in transverse diameter), to allow uniform assessment. Aspect ratios were maintained and there was no additional post-processing of images. The two blinded assessors used an Apple iPad (Apple Inc., Cupertino CA, USA) with pre-loaded images and a standard translucent 360 degree protractor (Cellco, China). Aligning the protractor with the anterior curve of the trachea at the level of the puncture and aligning the transverse axis with the posterior tracheal wall defined the geometric anterior tracheal midline. Using the aligned protractor the deviation from the midline in degrees was recorded. (Figure 1) This was followed by determination of the cranio-caudal position, based on the bronchoscopic images. This was deemed either appropriate, too caudal or too cranial depending on whether the puncture site was between the first and fourth tracheal rings or above or below these, respectively. The complete bronchoscopic video recordings were also available for the assessors to review on the tablet device. If there was greater than 10 degrees disagreement between the assessors or there was disagreement in terms of cranio-caudal positioning they were asked to review the images in question together to form a consensus. All statistical analysis was carried out using Prism for Mac OS X v6.0 (GraphPad Software Inc., La Jolla CA, USA). Deviation from the midline was assessed using an unpaired t-test. Deviation was also analysed with dichotomised data, a priori defining midline ± 30 degrees as appropriate and deviation beyond this as
inappropriate. Evaluation of the above, along with evaluation of longitudinal placement and number of multiple pass instances between the groups was evaluated using a Chi-square test.

**Figure 1** Measuring puncture deviation from the tracheal midline. Aligning the protractor with the anterior tracheal wall at the level of the puncture followed by rotating so that the transverse axis is parallel with the posterior tracheal wall defines the geometrical anterior tracheal midline. Deviation of the puncture was then determined in degrees.

**Results**

Over the 11 month recruitment period between August 2011 and July 2012 there were 72 eligible patients out of whom 55 were screened and 50 were enrolled, with 25 patients in each group. (Figure 2) No patient met exclusion criteria and no patient was deemed to require a surgical tracheostomy. No patient was found to have significant aberrant pre-tracheal vasculature in the ultrasound group. The groups were similar at baseline. (Table 1) One patient had recent cervical spine surgery and two patients had previous tracheostomy scars. Twenty-four patients in each group received the allocated intervention. One patient in the landmark group died after randomisation and before the tracheostomy was performed and one person in the ultrasound group made an unexpected recovery after randomisation and could be extubated without the need for tracheostomy. Procedural data were missing in one patient in the ultrasound group due to a protocol violation resulting in no recording being made. Follow-up data were complete for all but one patient in the landmark group who was lost to follow-up after transfer to another institution and therefore the final decannulation date is unknown. All data were analysed according to intention to treat.

**Figure 2** Consort Flowchart.

In both groups a third of the procedures were carried out by intensive care specialists, the remainder by senior trainees under supervision. Mean midline deviation in the ultrasound and landmark groups was 15 ± 3 versus 35 ± 5 degrees (P = 0.001), with a difference of 20 ± 6 degrees (95% CI 8.0 to 31.8). Appropriate midline puncture, defined a-priori as the anterior one third of the tracheal ring, or midline ± 30 degrees, was achieved in 20/23 (87%) patients in the ultrasound and 12/24 (50%) patients in the landmark group (RR = 1.74; 95% CI = 1.13 to 2.67; p = 0.006). Appropriate longitudinal placement was achieved in 21/22 (95%) in the ultrasound and in 21/22 in the landmark (95%) group (RR = 1.00, 95% CI = 0.88 to 1.14; P = 1.00). Longitudinal position could not be determined due to severe tracheitis in 2 patients in the landmark and 1 patient in the ultrasound group. First pass success rate was 20/23 (87%) in the ultrasound and 14/24 (58%) in the landmark group (RR = 1.49, 95% CI = 1.03 to 2.17; p = 0.028). Reduction in complication rate was not statistically significant, 5/23 (22%) in the ultrasound compared to 9/24 (37%) in the landmark group (RR = 0.58; 95% CI = 0.23 to 1.47; p = 0.24). Discounting “minor bleeding not requiring intervention” the complication rate was 2/23 (9%) and 2/24 (8%), which is comparable to that reported in the literature. One accidental decannulation and one pressure ulcer was noted in the ultrasound group during the follow-up period. There were no serious intermediate term complications. (Table 2) There were four deaths in each group, all related to the underlying disease process.
Discussion

Ultrasound guidance significantly improved the rate of first-pass puncture and puncture accuracy.

Ultrasoundographic anatomy of the anterior neck prior to tracheostomy was first described in 1995 [14] and a report of real-time ultrasound guided puncture for PDT was first published in 1999 [15]. Two-dimensional ultrasound using a linear array probe readily identifies the position and anatomical relation of important landmarks. These include the thyroid and cricoid cartilage, the tracheal rings, the thyroid gland and the carotid and jugular vessels. (Figure 3A and 3B) Aberrant vascular structures crossing the midline can 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, whilst a ninety degree rotation of the probe allows for an out of plane approach to guiding the needle (represented by an acoustic shadow) towards the midline. Care should be taken since the needle must enter the trachea almost directly below the puncture site, making the angle of insonation of the needle low, resulting in potential difficulties in identifying and discerning the needle tip from the shaft. Indirect ultrasonographic signs of the needle advancement such as indentation of the tissues can be used as additional guidance to direct the needle towards the anterior tracheal midline (See movie file: Additional file 1).

The theoretical advantage of using pre-procedural ultrasound lies with the ability to identify aberrant pre-tracheal 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 pre-tracheal soft tissue diameter or in children [16]. Intra-procedural 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 in real-time, not dissimilar to the technique routinely used in ultrasound guided vascular access.

It is common for patients receiving a tracheostomy to have anatomy that is considered ‘difficult’. This is most often due to obesity, or deformity from chronic musculoskeletal pathology or prior injuries and surgical procedures. The difficulties encountered in locating landmarks such as the crico-thyroid 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 [17,18]. Ultrasound has been successfully used in simulated models as well as difficult clinical cases to guide the tracheal puncture [19,20].

The finding that real-time ultrasound guided tracheal puncture has a significantly higher first-pass success rate has important implications not only in elective but also in emergency airway procedures. A number of currently used percutaneous emergency airway devices rely on
tracheal puncture and as these are reserved for “can’t intubate, can’t ventilate” scenarios, rapid and reliable access to the airway in these circumstances is of paramount importance.

To date there have been no studies that have reported on the incidence and degree of inappropriately positioned tracheal punctures and our data are the first to highlight this common occurrence during tracheal puncture guided by landmark anatomy. The extent to which deviation from the midline will influence the development of complications, either in the peri-procedural setting or later on, is also unknown. Vascular complications are relatively easy to detect but it is difficult to quantify their severity. Demonstration of the true incidence of long-term complications such as tracheal stenosis is difficult and often considered impossible in a study cohort due to the nature of the investigations required (CT scan, endoscopy). The rarity of serious or fatal complications makes a study powered to detect a significant difference in this regard impractical. On the other hand, there are plausible theoretical grounds and a large amount of observational data in the literature suggesting that multiple complications can potentially be avoided by an appropriately positioned tracheal puncture.

There can be little doubt that a significant proportion of serious complications in the immediate peri-procedural setting relate to unanticipated anatomical variation in vasculature [4]. Ultrasound has a sound theoretical benefit in this setting and a number of authors have reported changing the planned puncture location based on ultrasound findings in up to as many as 50% of their patients [21-23]. During dilation of the tract, laterally positioned punctures also change the force vectors, resulting from applying downward pressure onto an oblique section of the anterolateral trachea. A significant amount of force can thus be directed parallel rather than perpendicular to the tracheal wall (Figures 4 and 5). This can be particularly dangerous as it predisposes to bending of the guide-wire and subsequent para-tracheal dilatation of the tract, or tearing of the tracheal wall by the dilator itself. An appropriately positioned midline puncture can potentially prevent these complications.

Figure 4 Bronchoscopic views. Appropriately positioned tracheal puncture (A) and example of extremely lateral puncture with potential for complications (B). The asterisk marks the anterior tracheal midline.

Figure 5 Risk associated with lateral tracheal puncture. Downward force (Black arrow) applied during dilation of the tract can be broken up into force vectors which are perpendicular (Blue arrow) and parallel (Red arrow) to the tracheal wall. At a 90 degree angle all of the force is perpendicular. With the angle becoming more oblique, hitting the lateral curve of the tracheal wall, there is an increasing proportion of the downward force which is parallel to the wall and a decreasing proportion directed towards the tracheal lumen. This can lead to bending of the guide-wire and subsequent para-tracheal tract dilation or tearing of the tracheal wall itself.

The development of late complications can also be influenced by initial tracheostomy tube position. Published cases of serious late bleeding complications often arise in the setting of very laterally or caudally placed tracheostomy tubes eventually eroding into vascular structures [5]. Other long term complications such as tracheal stenosis and intermittent tracheostomy tube obstruction contributing to failed ventilator wean have also been reported as a consequence of inappropriate tracheostomy tube position [24-26]. Appropriate midline and longitudinal puncture position can therefore also have implications in reducing late complication rate.
In summary, although this study was not powered to detect a difference in rate of complications, there is sufficient evidence in the literature to support a link between appropriate tracheal puncture position and decreased complication rates both in the immediate procedural setting and also in the long term.

We conducted a prospective randomised controlled trial of utilising real-time ultrasound to guide tracheal puncture during PDT in a representative cohort of general adult intensive care patients. Ultrasound is generally available in intensive care units, and many consider real-time ultrasound mandatory for certain procedures including central venous cannulation and thoracocentesis. It was therefore reasonable to study the use of real-time ultrasound to guide tracheal puncture during PDT, as this technique can be broadly generalised.

**Strengths and limitations**

Strengths of the study include prospective randomisation and strict maintenance of allocation concealment, blinded assessment of primary outcome data as well as limited exclusion criteria and a high percentage of capture of eligible patients during the study period. Pragmatic inclusion of a representative cohort of proceduralists with various levels of expertise and training makes the data generalizable beyond the involved institutions. The end points were clearly defined, simple and clinically relevant and data was analysed using straightforward statistical methods.

Potential limitations include an operator skill mix biased towards the landmark-technique, in which most operators had significantly more experience compared to the ultrasound technique. This may have led to an underestimation of the effect size. The study examined a strict percutaneous tracheal puncture technique which may not be the method of choice in all institutions. The possible additional utility of ultrasound guidance is unclear if deep dissection is performed before the tracheal puncture or if bronchoscopy is used during the needle puncture to guide the needle. The number of puncture attempts was self reported and some procedural complications such as ‘minor bleeding not requiring intervention’ are difficult to define and can be subjective. Serious adverse events are rare and potential differences in length of ventilation or intensive care stay are likely to be small, therefore this study was not powered to demonstrate a difference in these outcome measures. Cranio-caudal placement of the tracheal puncture was difficult or impossible to determine in a small number of cases, such as in patients with significant tracheitis. There was a small apparent difference in baseline BMI between the two groups and although it has been demonstrated that morbid obesity does not influence safety or efficacy of PDT when ultrasound is used [23] there is no literature to determine if a difference exists when the landmark technique is utilised. The potentially incremental benefit of ultrasound over the landmark technique in the morbidly obese remains to be investigated.

**Conclusions**

Ultrasound guided tracheal puncture when compared to the landmark technique is more efficient with a significantly higher first-pass success rate. Ultrasound guided puncture is also more accurate, resulting in a significantly higher rate of appropriate midline punctures. Fewer procedural complications were observed in the ultrasound group, however this did not reach statistical significance. The present data support wider routine use of real-time ultrasound guidance for tracheal puncture during percutaneous tracheostomy.
Key messages

• Real-time ultrasound guidance improves accuracy of tracheal needle puncture during PDT, thereby potentially decreasing both short and long term complication rate.
• Real-time ultrasound guidance improves first-pass success rate of tracheal needle puncture during PDT, highlighting the potential utility during time-critical airway procedures.
• Fewer procedural complications were observed with the use of ultrasound guidance however this study was not powered to detect a statistically significant difference.

Abbreviations

PDT: Percutaneous dilatational tracheostomy

Competing interests

The authors declare that they have no competing interests.

Authors’ contributions

MR prepared the study protocol including conducting the preliminary literature review, submitted the research grant, supervised the conduct of the study at both participating sites, carried out data analysis and prepared the final manuscript. IS provided senior supervision of the conduct of the study at Nepean Hospital and contributed to the literature review, data analysis and final manuscript preparation. RHerkes and RHislop provided senior supervision of the clinical conduct of the study at Royal Prince Alfred Hospital and contributed to the development of the study protocol and grant preparation as well as human ethics submissions. DR and LW were the lead research coordinators at Royal Prince Alfred Hospital and Nepean Hospital respectively, they both participated in designing the study and data collection protocols and were responsible for coordinating data collection, follow-up and supervising study procedures for protocol adherence. All authors have read and approved the final manuscript.

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Written informed consent was obtained from the patient(s) or their relative(s) for publication of this manuscript and accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal.
The patient depicted in the video file “Additional file 1” is not a study participant. The patient and their next of kin have provided consent for the video to be recorded and used freely for education, presentation and publication purposes.
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**Additional file**

Additional_file_1 as MOV

Additional file 1 Ultrasound anatomy of the neck and real time ultrasound guided tracheal puncture. (17800 kb)

http://ccforum.com/content/supplementary/s13054-014-0514-0-s1.MOV
