

Prospective observational study of postoperative complications after percutaneous dilatational or surgical tracheostomy in critically ill patients

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Critically ill patients commonly require a tracheostomy. Surgical tracheostomy (ST) was first described in 1909,¹ and 50 years later percutaneous dilatational tracheostomy (PDT) was reported.^{2,3} An original multiple dilator technique⁴ was more recently refined as a single dilator approach.⁵ PDT has increased gradually in popularity, but, in the absence of large series, there is controversy about the relative advantages and disadvantages of the techniques.

PDT is usually done at the bedside in the intensive care unit by intensivists. This approach avoids the risks of transport outside the ICU and avoids the delays inherent in meeting complex operating room schedules. PDT may therefore be less costly⁶ and has become the method of choice for tracheostomy insertion in many ICUs for long-term airway management.⁷

Smaller descriptive (48–150 subjects)^{8–10} and randomised (24–200 subjects) studies^{11–20} have favourably compared PDT with ST, but the relative superiority of each procedure continues to be debated. Interestingly, when both procedures were conducted in the ICU, fewer differences were found, and ST was preferred in the ICU.^{21–23} Silvester et al found that both PDT and ST in the ICU were safe, but PDT had advantages of fewer delays (caused by the availability of surgeons) and better cosmetic results.²⁰ Most meta-analyses comparing PDT with ST^{6,24–27} have favoured PDT. The most recent of these found a non-significant trend towards fewer complications after PDT, with smaller skin incisions, less tissue trauma and a lower incidence of wound infection and peristomal bleeding than after ST.⁶

The accepted exclusions for PDT include emergency tracheostomy, enlargement of the thyroid gland, marked obesity, children, and difficulty palpating the cricoid cartilage.²⁸ Relative exclusions include coagulopathy,^{11,13,16,17,20,22} unstable cervical spine injury,^{17,19,20} previous tracheostomy,^{11–15,17–20} and difficult airway that would make urgent reintubation more difficult.¹⁶

At our ICU, single dilator PDT has been preferred for all patients requiring tracheostomy, except those with an anatomic abnormality or refractory coagulopathy, who receive surgical tracheostomy. Until now, no large study has reported the complications after single dilator PDT. In this 5-

ABSTRACT

Objective: To assess and describe postoperative complications of single dilator percutaneous dilatational tracheostomy (PDT) and surgical tracheostomy (ST) in a large series of critically ill patients.

Methods: A prospective observational study was conducted in 1163 critically ill patients in a university-affiliated tertiary referral hospital between 2002 and 2007. PDT was the procedure of choice for all critically ill patients requiring tracheostomy except for those with an anatomic abnormality or refractory coagulopathy, who underwent ST. Demographic and postoperative complication data were collected in a web-based database.

Results: 913 patients (79%) underwent PDT at the bedside in the ICU, and 250 (21%) underwent ST in the operating theatre. The tracheostomy tube was larger, and the duration of tracheostomy cannulation was shorter after PDT than after ST. The postoperative complication rate for PDT was 9.6% compared with 19.6% for ST ($P < 0.001$). Tracheal tube obstruction and displacement were significantly less frequent after PDT (obstruction 1.0% for PDT v 3.6% for ST, $P = 0.007$; displacement, 1.3% for PDT v 4.8% for ST, $P = 0.002$).

Conclusions: In a large heterogeneous group of critically ill patients, single dilator PDT was safe and had few postoperative complications. Although ST was used in higher-risk patients, those who underwent PDT were more likely to receive a larger-sized tracheostomy tube; they were also less likely to experience obstruction or displacement of the postoperative tracheostomy tube. These differences are probably related to a combination of patient selection, smaller, shorter tracheostomy tubes, and larger tissue incision size with ST.

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year prospective observational study, we report 1163 patients who underwent single dilator PDT ($n = 913$) or conventional ST ($n = 250$).

Methods

Between March 2002 and December 2007, 1163 patients received a tracheostomy at the Alfred Hospital, Melbourne, Victoria, a university-affiliated tertiary referral hospital with a Level 1 trauma centre and 36-bed Level 1²⁹ ICU. The Alfred ICU admits about 2000 medical, surgical and trauma patients annually, and provides a state service for adult major trauma, heart, lung and bone marrow transplantation, ventricular assist device and extracorporeal membrane oxygenation and hyperbaric medicine.

All ICU patients who required a tracheostomy during this period were eligible for the study, except for a small number with a specific upper airway abnormality, who were therefore managed by ear, nose and throat surgeons, with the potential for differences in clinical management between specialties. Consent for tracheostomy was sought from all patients, and they were prospectively enrolled in the study. The indication for tracheostomy was usually respiratory failure necessitating prolonged mechanical ventilation. When an enrolled participant required a subsequent tracheostomy during the hospital admission, only the first procedure was included in the study. Participants who underwent a failed PDT (which progressed to successful ST) were reported with the PDT patient group and subsequently excluded from further analysis of complications. The study was approved by the hospital's human research and ethics committee.

Tracheostomy techniques

In our ICU, PDT was the procedure of choice. Exclusion criteria for PDT included anatomic abnormalities involving the trachea, vessels or thyroid, abnormalities that prevented the operator identifying anatomic landmarks, and refractory coagulopathy. Patients deemed unsuitable for PDT and those undergoing other procedures in the operating theatre received a conventional ST in the theatre.

Percutaneous dilatational tracheostomy: PDT was performed at the bedside in the ICU by, or directly supervised by, an experienced consultant intensivist. The Ultraperc Portex percutaneous dilation tracheostomy kit with single stage dilator (Smiths Medical International, Hythe, UK) was used for all PDT procedures. A bronchoscope was always available at the bedside. After a 1–2 cm horizontal skin incision, blunt dissection was conducted with straight or curved forceps. A Seldinger-guidewire technique with a single tapered dilator was used to insert the appropriately sized Portex BlueLine Ultra tracheostomy tube between the first and second tracheal rings. An inner cannula was inserted into the tracheostomy tube.

Surgical tracheostomy: ST was performed in the operating theatre by the surgical team involved in the patient's

Table 1. Definitions of tracheostomy complications

| |
|--------------------------------------------------------------------------------------|
| Bleeding: moderate loss of blood, < 100 mL; major loss of blood > 100 mL |
| Displacement: tube displaced from trachea into pre-tracheal soft tissue |
| Unplanned decannulation: accidental complete dislodgement of tube |
| Desaturation: oxygen saturation < 90% |
| Obstruction: blocked tube inhibiting free passage of air into or out of lungs |
| Stomal infection: evidence of erythema, cellulitis or purulent discharge |
| Damage to local structures: injury to local tissue |

care or occasionally an ear, nose and throat surgeon. Most surgeons used a larger transverse cervical incision, dissection to the trachea, haemostasis as required, and then a transverse incision enabling access to the trachea below the second tracheal ring. Formation of an inferior flap with a stay suture secured onto the skin was the choice of trauma surgeons. A Portex BlueLine Ultra tracheostomy tube was then inserted and secured with skin sutures and foam Velcro tapes.

Data collection

Demographic data and data on postoperative complications were collected by two senior ICU nurses and entered into a web-based database. All entries were double-checked. All major complications were discussed with medical staff to ensure accurate interpretation of clinical events. Complications are defined in Table 1.

Statistical analysis

The primary aim of this study was to describe the postoperative complications of PDT and ST in ICU patients. We compared the demographics, patient admission category and postoperative complications in our PDT and ST patients. Univariate analysis for between-group comparisons used χ^2 tests for equal proportions or Fisher exact tests where numbers were small, the Student *t* test for normally distributed data, and Wilcoxon rank-sum tests otherwise, with results reported as mean (standard error) or median (interquartile range). Univariate analysis was performed using SPSS, version 12.0 (SPSS Inc, Chicago, Ill). A two-sided *P* less than 0.05 was considered to indicate a statistically significant difference.

Results

During the 5-year study period, 1163 patients were enrolled, with 913 PDT insertions performed in the ICU

Table 2. Patient and tracheostomy characteristics

| | Percutaneous dilatational tracheostomy (n = 913) | Surgical tracheostomy (n = 250) | P |
|---------------------------------------------|-----------------------------------------------------|------------------------------------|--------|
| Male, no. (%) | 605 (66.4%) | 163 (65.2%) | 0.72 |
| Age in years, mean (SE) | 52.5 (0.67) | 52.9 (1.27) | 0.76 |
| APACHE II score, mean (SE) | 17.59 (0.2) | 17.01 (0.19) | 0.19 |
| Diagnostic group, no. (%) | | | |
| Trauma | 341 (37.3%) | 119 (47.6%) | 0.003 |
| Neurosurgery | 151 (16.5%) | 16 (6.4%) | <0.001 |
| Cardiothoracic | 137 (15.0%) | 23 (9.2%) | 0.01 |
| General medical | 75 (8.2%) | 20 (8.0%) | 0.91 |
| General surgical | 56 (6.1%) | 14 (5.6%) | 0.75 |
| Burn | 22 (2.4%) | 38 (15.2%) | <0.001 |
| Cardiology | 49 (5.4%) | 9 (3.6%) | 0.26 |
| Respiratory | 36 (3.9%) | 5 (2.0%) | 0.14 |
| Infectious diseases | 23 (2.5%) | 4 (1.6%) | 0.39 |
| Vascular | 23 (2.5%) | 2 (0.8%) | 0.10 |
| Tracheostomy tube size, mean (SE) | 8.59 (0.02) | 8.13 (0.04) | <0.001 |
| Tracheostomy duration in days, median (IQR) | 15 (9–23) | 17 (10–28) | 0.004 |

SE = standard error. APACHE = Acute Physiology and Chronic Health Evaluation. IQR = interquartile range. Tracheostomy duration = period of time tracheostomy tube was in situ.

(79%), and 250 ST insertions in the operating theatre (21%). Patient characteristics are shown in Table 2. Half the patients (54%) who had a tracheostomy were trauma or neurosurgical patients. There was no statistically significant difference between the groups in relation to age, sex or APACHE score.

After PDT, tracheostomy cannulation was of shorter duration, and the tracheostomy tube size was significantly

larger than after ST (Table 2). No deaths were directly related to either procedure. PDT failed 15 times (1.6%), with 13 patients progressing to ST, and two patients having a repeat PDT. The postoperative complication rate was significantly lower after PDT than after ST (9.6% v 19.6%, $P < 0.001$) (Table 3).

Displacement

ST patients were more likely to experience postoperative displacement of the tracheostomy tube than PDT patients ($P = 0.002$) (Table 3). Twelve ST patients experienced tube displacement; six had failed reinsertion and translaryngeal intubation, two on the day of the ST and three on the day after. Another four had the tracheostomy tube reinserted through the existing stoma, and two were clinically ready for decannulation.

Six PDT patients experienced tube displacement, failed reinsertion and translaryngeal intubation, on Day 5 after PDT insertion (3 patients), and Days 6, 13, and 16 (one patient on each day), respectively. One of these displacements (Day 5) was associated with bradycardic arrest, with return of circulation following translaryngeal intubation and ventilation with 100% oxygen.

Tracheostomy obstruction

ST patients were also more likely than PDT patients to experience postoperative obstruction of the tracheostomy

Table 3. Postoperative complications

| Complication | PDT (n = 913) | ST (n = 250) | P |
|-------------------------|------------------|-------------------|------------------|
| Bleeding | 43 (4.7%) | 19 (7.6%) | 0.10 |
| Moderate | 40 (4.4%) | 15 (6.0%) | 0.37 |
| Major | 3 (0.3%) | 4 (1.6%) | 0.06 |
| Displacement | 12 (1.3%) | 12 (4.8%) | 0.002 |
| Unplanned decannulation | 7 (0.8%) | 2 (0.8%) | 0.70 |
| Desaturation | 10 (1.1%) | 2 (0.8%) | 0.95 |
| Obstruction | 9 (1.0%) | 9 (3.6%) | 0.007 |
| Stomal infection | 6 (0.6%) | 5 (2.0%) | 0.11 |
| Damaged pilot tube | 1 (0.1%) | 0 | 0.49 |
| Total | 88 (9.6%) | 49 (19.6%) | <0.001 |

PDT = percutaneous dilatational tracheostomy. ST = surgical tracheostomy.

tube ($P=0.007$) (Table 3). Of the nine postoperative obstruction events after ST, six were related to tracheostomy position within the trachea, and three to tracheal mucosal injury. One of the latter patients required surgical intervention. Interventions in ST patients included changing the tracheostomy tube to a longer, adjustable flange tracheostomy tube (5 patients), changing the tracheostomy tube to the same type of tube (3 patients) and bronchoscopy (1 patient).

In PDT patients, postoperative obstruction was caused by blockage of the inner lumen of the tube with secretions on five occasions and by abnormal mucosal tissue at the tip of the tracheostomy tube on four occasions. One of these patients experienced cardiopulmonary arrest and, after stabilisation, was transferred to the operating theatre for surgical debridement of a mucosal flap. Interventions for PDT patients included bronchoscopy (2 patients), tracheostomy tube change (2 patients), decannulation (1 patient), and surgical debridement (1 patient).

Bleeding

The rate of postoperative bleeding was higher in ST patients than in PDT patients, but the difference did not reach statistical significance ($P=0.10$) (Table 3). Of the four ST patients with a major postoperative bleed, two required surgical intervention in the operating theatre, and one required a red blood cell transfusion. Of the three PDT patients with a major postoperative bleed, two required surgical intervention in the operating theatre, and the other required a red blood cell transfusion, although the bleed resolved with packing.

Of the moderate postoperative bleeds after ST (15 patients), all resolved with simple measures, including packing with a haemostatic dressing (8), application of silver nitrate (1), or bronchoscopy (2). Of the moderate postoperative bleeds in PDT patients (40 patients), four required surgical intervention in the operating theatre, one a red blood cell transfusion and one a clotting factor transfusion, while one required reintubation with an endotracheal tube. The remaining moderate bleeds in the PDT group resolved with simple measures, including packing with a haemostatic dressing (24), suture insertion (6), application of silver nitrate (1), or bronchoscopy (2).

Unplanned decannulation

The two groups had similar rates of unplanned decannulation (Table 3). In most cases, this was due to self-removal by an uncooperative patient (PDT, 5 patients; ST, 2).

Discussion

This is the largest prospective study of postoperative complications relating to single dilator PDT ($n=913$) and con-

ventional ST ($n=250$) yet reported. In this series, the procedure of choice was PDT, and ST was reserved for higher-risk patients. Postoperative complications were less after PDT (9.6%) than after ST (19.6%; $P<0.001$), demonstrating that single dilator PDT is a safe technique in selected ICU patients. Furthermore, obstruction and displacement of the tracheostomy tube, with or without life-threatening complications, was less frequent after PDT.

Comparison of these tracheostomy complication rates with other published rates is difficult. Most studies comparing PDT with ST describe multiple dilator PDT.^{8-18,20-23} Only one study compared the single dilator PDT technique with ST.¹⁹ In addition, the diversity of definitions of tracheostomy complications between studies increased the variability of reported complications.³⁰ In our study, we recorded all abnormal clinical events according to predefined criteria (Table 1). However, if we had reported only postoperative complications with clinical sequelae, such as transfer to the operating theatre for surgical intervention (PDT, 7; ST, 3), translaryngeal intubation (PDT, 11; ST, 6), bronchoscopy (PDT, 3; ST, 1), tracheostomy tube change (PDT, 2; ST, 7), blood product transfusion (PDT, 3; ST, 1) or provision of education to nurses following obstruction of the inner cannula (PDT, 3; ST, 0), then the complication rate would have been even lower (PDT, 3.2% v ST, 7.2%; $P=0.07$).

The postoperative complication rate for PDT in our series (9.6%) is similar to previously reported rates for single dilator (2%–16%)³¹⁻³⁴ and multiple dilator (4%–18%) PDT.^{10,17,18,20-22} The complication rate for ST (19.6%) is also comparable with previously reported rates of 2%–36%.^{10,17,18,20-22} We found postoperative complications were significantly fewer after PDT than ST (9.6% v 19.6%, $P<0.001$), but these rates are likely to have been influenced by patient selection. High-risk patients selectively received ST in the operating theatre. Another study also found increased perioperative complications in patients selected for ST in the operating theatre following exclusion from PDT by factors such as large neck girth or inability to extend the neck.²² We suggest increased vigilance for postoperative complications, particularly obstruction and tube displacement, in higher-risk patient groups receiving ST.

In contrast to the meta-analysis by Higgins et al,⁶ we found the rate of tracheostomy tube obstruction and displacement to be greater after ST. This may be in part related to patient selection and also fit of the tracheostomy tube. Tube fit and subsequent angle in the airway of a patient with increased neck girth may predispose to tracheal mucosal irritation, resulting in granulation tissue and obstruction, or a partial occlusion caused by the tip of the tracheostomy tube abutting the tracheal wall. Furthermore, a standard tracheostomy tube may have an increased propensity for displacement in patients with unusually large

necks if not sitting securely in the trachea. Accidental decannulation has been reported in obese patients, prompting the suggestion that extended-length tracheostomy tubes be used routinely in these patients.³⁵

Another potential reason for increased displacement after ST may have been the smaller tracheostomy tube size often favoured by surgeons at our institution. Intensivists usually preferred larger tubes to minimise airway resistance and pressures. In addition, the smaller incision and tight fit of the tracheostomy tube after PDT may decrease the risk of displacement compared with the larger surgical incision.¹³

The percentage of those with loss of airway (displacement and unplanned decannulation) who required translaryngeal intubation was similar after PDT (47%) and ST (43%). No deaths were associated with loss of airway, although one patient in the PDT group experienced a bradycardic arrest.

After PDT, the narrow tract and lack of a formal stoma may increase the risks of accidental decannulation.²² In our study, reinsertion of a displaced tube was difficult after PDT on six occasions, a mean of 8 days after insertion (range, 5–16 days). However, five of the six patients with a displaced tube after ST also required translaryngeal intubation within 2 days of insertion.

Tracheostomy tube obstruction was uncommon in both groups (PDT, 1% v ST, 3.6%), perhaps because regular inspection of the inner cannula was part of nursing practice for all patients. When obstruction occurred, it was often related to tracheal mucosal damage (PDT, 4 v ST, 3) or the tracheostomy tube being misdirected and abutting the wall of the trachea (PDT, 0 v ST, 6). Single dilator PDT may carry less risk of damage to the posterior tracheal wall (0/25) than multiple dilator PDT (2/25).⁵ Tracheostomy tube obstruction can be catastrophic, with one PDT patient having a tissue flap which led to complete respiratory arrest. This was corrected by urgent surgical exploration and debridement of the tissue flap. Tracheal mucosal damage causing tube obstruction was equally common in our two groups. The misdirected angle of the tracheostomy tube abutting the wall of the trachea was more common after ST, and may have been related to inappropriate selection of tracheostomy tube.

Study limitations

In this study, patients with anatomic abnormalities or higher risk of complications were selected for ST. Patient selection therefore in part explains the lower complication rate after PDT. Although not a randomised controlled trial, this study describes the real world use of PDT versus ST, based on clinical criteria for patient selection.

Conclusions

Single dilator percutaneous dilatational tracheostomy (PDT) is safe and can be recommended for critically ill patients who have no anatomic abnormalities of the trachea, vessels or thyroid, when normal landmarks are palpable, and when there is no significant coagulopathy. ST is also safe, although we found higher rates of tube obstruction, displacement, and complications with clinical sequelae than after PDT. Overall, postoperative complication rates were very low. Patients in the ST group were perhaps inherently more at risk of complication as they were likely to have been selected for ST because of anatomic abnormality. Careful selection of the optimal tracheostomy tube size and length to fit a patient's anatomy might minimise obstruction and displacement after both types of tracheostomy and warrants further study.

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