

Comparison of the effects of different percutaneous tracheotomy techniques on acute tracheal trauma

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Aim: As it can easily be performed at the bedside with minimal morbidity, percutaneous dilatational tracheotomy (PDT) is preferred over surgical tracheotomy. The aim of this study is to compare the effects of different PDT techniques on posterior tracheal wall injury.

Materials and methods: The study was conducted at the Gazi University Laparoscopy Training Center after approval was granted by the ethics committee. After sedation with xylazine/ketamine, electrocardiography, peripheral oxygen saturation, and blood pressure were monitored. Propofol was used to achieve the desired level of sedation during the procedure. There were 16 pigs, randomly allocated into 4 groups. Multiple, single, forceps, and twist dilator techniques were performed in groups I, II, III, and IV, respectively. At the end of the course all pigs were sacrificed and tracheas were harvested for macroscopic and histopathological evaluation.

Results: Macroscopic evaluation revealed erythematous/hemorrhagic and ulcerative lesions on the posterior wall of all samples. Histopathological injury was observed in all samples and was similar in all groups. Procedural time was significantly longer in group I than in all other groups ($P < 0.05$).

Conclusion: Although the results are conflicting, bronchoscopy-aided PDT is believed to reduce complications. In our study, PDTs were performed without bronchoscopy, and posterior wall injury was observed in all samples. Therefore, we suggest using bronchoscopy to reduce procedure-related complications and improve patient safety during PDT.

Key words: Percutaneous dilatational tracheotomy, tracheal injury, swine model

1. Introduction

Percutaneous dilatational tracheotomy (PDT) has been one of the most common surgical procedures performed in intensive care units since it was defined by Sheldon et al. (1,2). The procedure can easily be performed at the bedside and has minimal morbidity and mortality; therefore, PDT is preferred over surgical techniques (3,4). The first step in most PDTs uses Seldinger's technique for accessing the trachea. The techniques used differ once access to the trachea is achieved. As the laryngeal and tracheal anatomic structures of pigs are similar to those of humans, this study was conducted in pigs. The aim of the current study was to compare the 4 different PDT techniques that use Seldinger's technique for accessing the trachea in terms of procedural time, the procedure's difficulty level, and the incidence and severity of posterior tracheal wall injury.

2. Materials and methods

The study protocol was approved by the Gazi University Animal Ethics Committee and was performed according

to the guidelines of the Research Committee of Gazi University Faculty of Medicine. This study used 16 male pigs, between 35 and 45 kg, scheduled for laparoscopy training courses at the Gazi University Laparoscopy Training Center. As the anatomic structures of the larynx and trachea of humans and pigs are similar, and the size of the pig trachea is nearly the same as the human trachea (5), standardized tracheotomy sets were used in the current study. Animals were housed in individual cages in a temperature-controlled environment and fed a standard diet and tap water ad libitum.

The pigs were fasted for 8–10 h before surgery. The animals were transferred to the operating room 15 min after sedation with ketamine (10 mg kg⁻¹, intramuscular) and xylazine (2 mg kg⁻¹, intramuscular), and standard monitoring with 3-lead electrocardiography, peripheral oxygen saturation (SpO₂), and noninvasive blood pressure was performed. An ear vein was cannulated with a 22-G venous cannula, and lactated Ringer solution was administered at a rate of 2.0–5.0 mL kg⁻¹. Propofol was

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titrated to achieve an adequate level of sedation and protect spontaneous breathing during the PDT procedure, given as bolus doses (0.25–0.5 mg kg⁻¹, intravenous) when needed.

The current study compared 4 widely used techniques, and the animals were randomly allocated to 4 groups as follows: group I (n = 4): multiple dilator PDT; group II (n = 4): single dilator PDT; group III (n = 4): forceps PDT; and group IV (n = 4): twist dilator PDT.

The animals were fixed to the operating table in the supine position by the 4 extremities, with their heads extended. The insertion point was determined by palpating the cricoid cartilage and was located caudally to thyroid cartilage. The insertion point was determined as the space between the 2nd and 3rd tracheal rings. After infiltrating 3 mL of 1% lidocaine for local anesthesia, a 1-cm transverse skin incision below the cricoid cartilage was performed. While fixing the trachea with the nondominant hand, a 14-G needle attached to a 5-mL syringe filled with 2.5 mL of normal saline was directed to the trachea while aspirating with constant power. After confirming correct placement by observing the bubbles, the syringe was removed and a J guide wire was transferred to the trachea through the catheter over the needle. From that point, 4 different tracheotomy techniques were used.

Group I (multiple dilator PDT): A modified Seldinger technique as described by Ciaglia et al. (3) was used for PDT. Multiple tracheal dilators were used sequentially over the J guide wire to dilate the tissue and tracheal stoma. Following the insertion of the 34-Fr dilator, an 8.0-mm tracheotomy tube was inserted using a 28-Fr loading dilator.

Group II (single dilator PDT): A modified Seldinger technique as described by Ciaglia et al. (3) was used for PDT. A predilator was used to partially dilate the cutaneous tissue, subcutaneous tissue, and trachea, followed by an additional dilation for an 8.0-mm tracheotomy tube with a Blue Rhino dilator with its special applicator transferred over the guide wire into the trachea. The Blue Rhino dilator was removed, and an 8.0-mm tracheotomy tube was placed into the trachea over the guide wire.

Group III (forceps PDT): Using Seldinger's technique, the kit's small dilator was introduced into the trachea over the J guide wire for predilation. The forceps (grooved Howard-Kelly forceps) were then introduced over the guide wire into the trachea; the handles of the forceps were opened and the stoma was fully dilated. Finally, the forceps were removed, and an 8.0-mm tracheotomy tube over a plastic trocar was passed over the guide wire into the trachea.

Group IV (PercuTwist PDT): The PercuTwist screw dilator was placed over the guide wire via its central lumen and was advanced by clockwise rotation using

Seldinger's technique. After removing the screw dilator via counterclockwise rotation, an 8.0-mm tracheotomy tube, preloaded onto its introducer, was fed into the trachea via the guide wire.

After placing the tracheotomy tube in all groups, the guide wire and introducer or trocar were removed. Mechanical ventilation was initiated after appropriate placement of the cannula was confirmed with auscultation.

Isoflurane (1.0%) was administered in air/oxygen (60/40) to maintain anesthesia. Rocuronium (0.1 mg kg, intravenous) was used for neuromuscular blockade, and an intravenous dose of 0.01 mg kg rocuronium was added during the procedure when needed.

The difficulty of the procedures was graded using Frova and Quintel's classification as follows: Grade I: no difficulties; Grade II: some difficulties encountered but possible; and Grade III: procedure abandoned. Bleeding was also classified as follows: 1) no or minimal bleeding (no bleeding observed or minimal bleeding requiring no intervention); 2) medium bleeding (special wound and/or vasoactive drugs used to control bleeding); and 3) serious bleeding (bleeding required surgical intervention) (6).

The animals were sacrificed with 20 mg kg⁻¹ intravenous pentothal after surgery, and their tracheas were harvested following cardiac arrest. Posterior wall lesions such as erythematous, hemorrhagic lesions and ulcerations were evaluated according to their size.

The pathologist was blinded to the percutaneous tracheotomy technique used. The features of the lesions were recorded. All tracheas were placed in 10% formaldehyde for histopathological evaluation.

Trachea samples were fixed and embedded in paraffin. The paraffin blocks were then serially sectioned into 4–5 µm sections. After hematoxylin-eosin staining (HE, 200×), the histopathological changes of representative sections of the posterior wall of the trachea were graded using the following grading score. Grade 0: normal, Grade 1: erythema and edema but no ulceration; Grade 2: superficial ulceration of mucus membrane; Grade 3: deep ulceration of mucus membrane, Grade 4: deep ulceration of mucus membrane and severe perichondrium inflammation.

Comparison of group characteristics were assessed by using Kruskal–Wallis test. The Bonferroni adjusted Mann–Whitney U test was used after significant Kruskal–Wallis results to determine which group differed from the other. A P-value of 0.05 or less was considered statistically significant.

3. Results

All groups were comparable in terms of demographic data, duration and difficulty of surgery, bleeding, and the histopathological, erythematous hemorrhagic, and ulceration scores of the subjects (Table). Durations of

Table. Demographic data, difficulty, bleeding, and histopathological, erythematous/hemorrhagic, and ulceration scores of the subjects.

	Group I (n = 4)	Group II (n = 4)	Group III (n = 4)	Group IV (n = 4)	P-value
Age (months)	3.75 ± 0.28	3.62 ± 0.25	3.37 ± 0.47	3.62 ± 0.47	0.595
Weight (kg)	34.77 ± 2.61	32.75 ± 3.00	32.75 ± 3.48	32.40 ± 3.93	0.734
Procedural time (min)	9.00 ± 0.40*	6.25 ± 0.64	6.12 ± 0.62	6.62 ± 0.47	0.00
Difficulty score	1.0 (1-1)	1.0 (1-1)	1.0 (1-1)	1.0 (1-1)	>0.5
Bleeding score	3.12 ± 0.45	3.04 ± 0.27	2.94 ± 0.33	3.11 ± 0.26	0.862
Histopathological grade	2.75 ± 0.95	2.75 ± 0.95	3.00 ± 1.15	2.25 ± 1.25	0.657
Erythematous and hemorrhagic lesions (mm)	1.75 ± 1.35	1.72 ± 1.35	1.92 ± 1.02	1.00 ± 0.40	0.490
Ulceration (mm)	0.25 ± 0.37	0.25 ± 0.37	0.20 ± 0.40	0.25 ± 0.50	0.178

Data are presented as median (min-max) for difficulty score and mean ± SD for other parameters. *: P<0.05 for Group I vs. Groups II, III, and IV.

the tracheotomy procedure were significantly longer in Group I than in Groups II, III, and IV ($P < 0.05$). Difficulty of surgery, bleeding, and histopathological, erythematous-hemorrhagic, and ulceration scores were similar. No difficulties, major bleeding, pneumothorax, subcutaneous emphysema, or hemodynamic instability were encountered during the tracheotomy procedure in any of the groups. Macroscopic evaluation revealed erythematous, hemorrhagic lesions and ulcerations on the posterior wall of all tracheas. All groups were comparable in terms of histopathological injury (Figure 1) and macroscopic appearance of ulcerative lesions of the posterior tracheal walls (Figure 2).

4. Discussion

Percutaneous dilatational tracheotomy is the technique of choice in most intensive care units around the world (7,8).

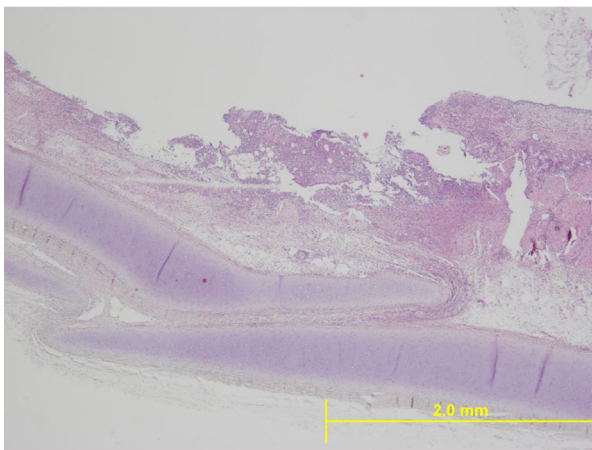


Figure 1. Photomicrograph of the histologic section of the posterior tracheal wall showing the presence of deep ulcer. There is severe perichondrium inflammation (HE staining 100×).

After much research into a less invasive method, Shelden et al. (1) reported a new technique of tracheotomy that can easily be performed without the use of surgical instruments. There are increasing numbers of studies in the literature that report the benefits of percutaneous techniques over traditional methods, such as decreased complication rates, thereby making percutaneous techniques a popular option (9-11). Thus, studies to develop different percutaneous techniques are now becoming a greater concern. In 1985, Ciaglia et al. (3) defined a new technique for PDT that uses multiple, increasing-sized serial dilators. This new technique has many advantages, such as decreased skin incision and soft tissue dissection. Thus, the percutaneous technique has become the technique of choice for tracheotomy among

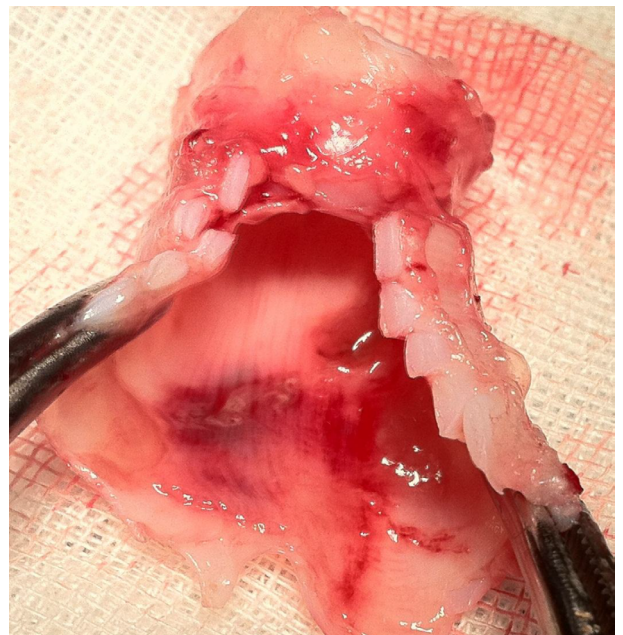


Figure 2. Ulcerative lesions of the posterior tracheal wall.

surgeons and intensive care physicians. Different types of percutaneous tracheotomy methods were developed after Ciaglia et al.'s success (3), all of which have been validated by many authors. The most preferred PDT techniques are as follows: multiple dilator, single dilator, forceps dilator, and twist dilator. Despite the success and widespread use of these techniques, concerns remain regarding potential airway complications, especially with the techniques involving multiple dilators. Although PDT techniques are less traumatic than surgical methods, they can have specific and even mortal complications, such as extensive bleeding, pneumothorax, subcutaneous emphysema, and posterior tracheal wall injury (7,12,13).

The incidence of posterior tracheal wall injury is reported in 2%–4% of the literature (4,14). However, Trottier et al. (15) reported the incidence of posterior wall injury at 29% following their study, in which they performed the procedures under the guidance of fiberoptic bronchoscopy. Nickells et al. (7) assessed the complications of percutaneous tracheotomy in sheep and also observed posterior tracheal wall injury in all animals. Our results confirmed the study by Nickells et al. (7), as we observed posterior tracheal wall injury in all pigs. The lower rates of posterior wall injury may be related to the design of the study (16–18). In these studies, tracheas were not harvested, and histopathological examination was not performed. Therefore, we believe that these studies failed to show the real incidence of posterior tracheal wall injury, and it can be speculated that percutaneous methods are not completely safe.

The incidences of life-threatening complications, such as pneumothorax and subcutaneous emphysema, were reported as 0.8% and 1.4%, respectively, in a review of 21

studies on 3012 patients by Fikker et al. (15). In our study, neither pneumothorax nor subcutaneous emphysema was observed.

The duration of the PDT procedure differs according to the technique used. Johnson et al. (17) compared the multiple and single dilator techniques in terms of procedural time and found that the duration of the serial dilator technique is significantly longer than the single dilator technique (10.01 ± 4.26 vs. 6.01 ± 3.03 min). Our results were in accordance those of with Johnson et al. (17), as the procedural time was significantly longer in the serial dilator group than in the other 3 groups. The need for multiple dilation using serial dilators in the multiple dilator technique was the cause of the longer procedural time in this group in both studies. Time needed for PDT in our study was shorter than the time mentioned in the literature. A possible explanation could be the comfort of the performer due to the relative ease of performing PDT on pigs in comparison with critically ill patients in an intensive care environment (18).

Delaney et al. (10) reviewed randomized controlled studies comparing PDT and surgical tracheotomy in critically ill patients in a metaanalysis of 1212 patients. They reported that fiberoptic bronchoscopy was used in less than half of them. Our study design was similar in this context, as we were unable to use a fiberoptic bronchoscopy during the procedures and this is a limitation of our study.

Our results were inconsistent with the previous clinical studies in terms of less injury to the posterior wall during PDT. Therefore, using a fiberoptic bronchoscope may prevent posterior wall injury and decrease the frequency of complications related to the PDT procedure.

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