World J. Surg. 25, 296–301, 2001
DOI: 10.1007/s002680020087

WORLD
Journal of
SURGERY

Bedside Percutaneous Tracheostomy: Clinical Comparison of Griggs and Fantoni Techniques

Christian Byhahn, M.D.,[1] Hans-Joachim Wilke, M.D.,[1] Volker Lischke, M.D.,[1] Thorsten Rinne, M.D.,[2] Klaus Westphal, M.D.[1]

[1]Department of Anesthesiology, Intensive Care Medicine, and Pain Control, J.W. Goethe-University Hospital Center, Theodor-Stern-Kai 7, D-60590 Frankfurt, Germany
[2]Department of Thoracic and Cardiovascular Surgery, J.W. Goethe-University Hospital Center, Theodor-Stern-Kai 7, D-60590 Frankfurt, Germany

Abstract. Elective tracheostomy is widely considered the preferred airway management of patients on long-term ventilation. In addition to open tracheostomy, a number of percutaneous procedures have been introduced during the last two decades, among them techniques according to Griggs (guidewire dilating forceps, or GWDF) and to Fantoni (translaryngeal tracheostomy, or TLT). The aim of the study was to evaluate these two techniques in terms of perioperative complications, risks, and benefits in critically ill patients. A series of 100 critically ill adult patients on long-term ventilation underwent elective percutaneous tracheostomy, either according to the Griggs ($n = 50$) or Fantoni ($n = 50$) technique. Tracheostomy was performed under general anesthesia at the patient's bedside. The mean (±SD) operating times were short, 9.2 ± 3.9 minutes (TLT) and 4.8 ± 3.7 minutes (GWDF) on average. Perioperative complications were noted in 4% of patients during either TLT or GWDF and included massive bleeding, mediastinal emphysema, posterior tracheal wall injury, and pretracheal placement of the tracheostomy tube. With regard to oxygenation, pre- and postoperative arterial oxygen tension divided by the fraction of inspired oxygen (PaO_2/FiO_2) ratios did not vary significantly, and no perioperative hypoxia was noted regardless of the technique used. We conclude that both TLT and GWDF represent attractive, safe alternatives to conventional tracheostomy or other percutaneous procedures if carefully performed by experienced physicians and under bronchoscopic control.

Tracheostomy is one of the oldest surgical procedures, and in past decades it has become the method of choice for management of critically ill patients who require long-term mechanical ventilation. It lowers the incidence of laryngeal injury [1] and nosocomial airway infection [2, 3], improves weaning from the ventilator and airway toilet [1, 3], and may shorten the intensive care unit (ICU) stay [3]. In addition to conventional surgical tracheostomy, a number of percutaneous techniques have been introduced during the past two decades [4–7]. At present, percutaneous dilatational tracheostomy (PDT) according to Ciaglia et al. [5] and the guidewire dilating forceps (GWDF) technique introduced by Griggs et al [7] are the most common in use and have been recognized as equally safe procedures when compared to surgical tracheostomy [8–11].

Correspondence to: C. Byhahn, M.D., e-mail: c.byhahn@em.uni-frankfurt.de

With translaryngeal tracheostomy (TLT), according to Fantoni and Ripamonti [12], another percutaneous procedure has become available that is different from PDT and GWDF in some important points. Because the tracheostomy tube is pulled from inside the trachea to the outside at once, progressive dilation of the trachea is no longer necessary. Furthermore, ventilation during the procedure can be maintained via a thin endotracheal tube, the end of which is positioned distal to the tracheostomy site. Therefore TLT minimizes the risks of perioperative hypoxia or bleeding and seems to be feasible even in patients with severe respiratory failure or massive coagulopathy.

To compare GWDF and new TLT in terms of practicability and perioperative complications under clinical conditions, 50 patients who underwent TLT or GWDF at the bedside were prospectively studied in terms of perioperative oxygenation, bleeding, and complications.

Materials and Methods

The setting of the study were two surgical ICUs (24 beds total) of a university hospital center. During a 16-month period 100 ICU patients on long-term ventilation who underwent elective tracheostomy were investigated prospectively. Adult respiratory distress syndrome (ARDS), septic shock, pneumonia, low cardiac output, and neurologic disorders (e.g., stroke, intracerebral hemorrhage, severe head trauma) were the most common indications for long-term mechanical ventilation. During the first 8 months of the study, tracheostomy was done according to Fantoni's technique ($n = 50$), whereas during the next 8 months the GWDF technique of Griggs et al. was employed ($n = 50$). All tracheostomies were performed by the same team, which had a formal experience of more than 200 previous percutaneous tracheostomies, including all techniques available.

In each instance tracheostomy was performed at the patient's bedside. All patients received general intravenous anesthesia consisting of propofol 3 mg/kg, fentanyl 0.2 mg, and pancuronium 0.1 mg/kg for muscle relaxation during the procedure. Five minutes before tracheostomy, the fraction of inspired oxygen concentra-

Table 1. Coagulation variables in patients who underwent elective percutaneous tracheostomy.

Variable	TLT (n = 50)	GWDF (n = 50)
Endotracheal intubation (days)	10.7 ± 5.6 (2–32)	9.6 ± 5.1 (2–25)
Prothrombin time (%)	69.7 ± 13.0* (38–100)	63.9 ± 13.9* (34–98)
Partial thromboplastin time (s)	43.8 ± 11.9 (29–87)	43.7 ± 9.7 (23–76)
Platelet count/nl	213 ± 139 (43–669)	182 ± 125 (51–595)
Heparin (IU/hr)	636 ± 253 (200–1,000)	544 ± 235 (100–1,000)

Data are presented as the mean ± SD (range).

TLT: translaryngeal tracheostomy; GWDF: guidewire dilating forceps.

*$p < 0.05$ when TLT was compared to GWDF.

tion was reduced to the preoperative level. If, with this regimen, oxygen saturation (SaO_2) measured by pulse oximetry was less than 92%, the FiO_2 was increased stepwise to maintain the SaO_2 higher than 92%. The electrocardiogram, arterial blood pressure, and oxygen saturation were monitored continuously. Arterial blood gas samples were obtained 1 hour before and 1 hour after tracheostomy. Coagulation parameters (prothrombin time, partial thromboplastin time, platelets) were determined on the day of the procedure. All patients were given heparin continuously (Table 1). Infection of the tracheostomy site and severe coagulopathy (except for two patients in the TLT group) were considered contraindications for tracheostomy.

Translaryngeal Tracheostomy

Regardless of the technique used, the patient's neck was slightly hyperextended, and the surgical area was cleaned and prepared. When TLT was performed, all maneuvers took place under bronchoscopic visualization, and the Translaryngeal Tracheostomy Kit (Mallinckrodt Medical GmbH, Hennef, Germany) was used. First, the endotracheal tube was pulled back to gain access to the trachea. Then a slightly curved puncture needle was introduced into the tracheal lumen at the midline between the second and third tracheal ring, followed by introduction of a special guidewire. The guidewire was advanced retrogradely parallel to the endotracheal tube. When the wire was seen in the pharynx, it was caught with a Magill's forceps, pulled out of the patient's mouth, and connected to the tracheostomy tube. The endotracheal tube in place was removed and replaced with a thin endotracheal tube. The tracheostomy tube was then passed over the guidewire and advanced beyond the pharynx and larynx into the trachea (Fig. 1). By performing rotating movements at the wire's distal end, the tube's conically shaped tip penetrated the anterior tracheal wall, muscular structures, and skin (Fig. 2). It was then cut at a predetermined length and, after the thin endotracheal tube was removed, turned 180 degrees by means of an obturator. A thin tube with a valve was connected to a designated port of the tracheal cannula. The cannula's cuff was inflated by means of this tube, and the cannula was then connected to the respirator. The tracheal cannula size used for TLT was 9.5 mm in all patients. The correct position of the tracheostomy tube was confirmed by bronchoscopy and auscultation of the lungs.

Fig. 1. When the endotracheal tube in place had been replaced under direct laryngoscopy with the thin tube of the set, the tracheostomy tube connected to the guidewire was advanced through the patient's mouth into the trachea. The deflated cuff of the tracheostomy tube can be seen at the top end of the tube.

Guidewire Dilating Forceps Technique

The Sims Portex Percutaneous Tracheostomy Kit (Sims Portex, Hythe, Kent, UK) was used for GWDF. After bronchoscopically controlled puncture of the trachea in the midline between the second and third tracheal cartilage ring, a guidewire was introduced, and the needle was removed. A small dilator was passed over the guidewire into the trachea. After removing the dilator a 1 cm transverse skin incision was made, and modified Howard-Kelly forceps were passed over the wire to dilate the pretracheal tissues first (Fig. 3). The dilating forceps were then introduced through the anterior tracheal wall into the trachea, and the tracheal wall was dilated under bronchoscopic control to prevent traumatization of the posterior wall. After dilation, a 9.0 mm tracheostomy tube was introduced over the guidewire and a stylet placed in the tracheal lumen. When the correct position had been confirmed bronchoscopically, the cuff was inflated and the tracheostomy tube connected to the ventilator.

Regardless of the technique chosen for placing the tracheostomy tube, a low pressure cuff was used in each instance to minimize the hazard of late posttracheostomy stricture. For all techniques, the procedure concluded with a final bronchoscopy. Any aspirated blood and secretions were suctioned off.

Statistics

Once the homogeneity of the data was confirmed, the Wilcoxon-Mann-Whitney test was used to compare the data in terms of the mean and standard deviation (SD). All statistical calculations were performed using GraphPad InStat Version 3.00 (GraphPad Software, San Diego, CA, USA). Statistical significance was confirmed with $p < 0.05$.

Fig. 2. Pulling the wire's neckside end under digital counterpressure, the tracheostomy tube is advanced through the anterior tracheal wall and the soft tissues of the neck. Note that virtually no bleeding occurs.

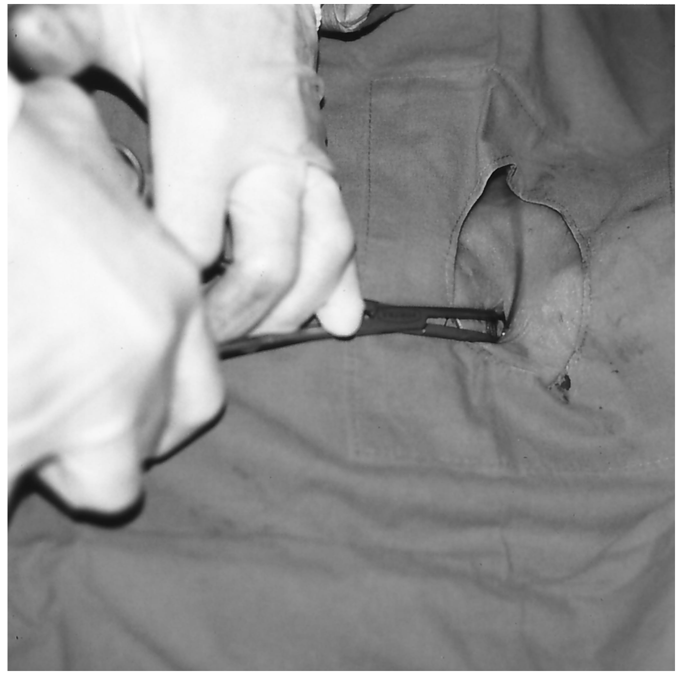

Fig. 3. After a small transverse skin incision had been made, the dilating forceps were passed over the guidewire, and the pretracheal soft tissues were dilated.

Results

A total of 100 long-term ventilated adult patients (ages 18–85 years) of two surgical ICUs underwent elective tracheostomy during a 16-month period. Tracheostomy was done percutaneously at the patient's bedside, using either Fantoni's TLT ($n = 50$) or Griggs' GWDF ($n = 50$) technique. Coagulation parameters of the patients who underwent tracheostomy and the time intervals between endotracheal intubation and tracheostomy are given in Table 1.

Operating times were significantly shorter for the GWDF technique than for TLT ($p < 0.05$, Table 2). During TLT a significantly higher FiO_2 had to be employed postoperatively to maintain stable oxygenation, whereas with GWDF oxygenation variables remained almost unchanged. The pre- and postoperative arterial oxygen tension (PaO_2) and fraction of inspired oxygen (FiO_2) ratios did not vary significantly regardless of the technique performed. Because deterioration of gas exchange and oxygenation was slight and temporary with both tracheostomy methods, no patient became hypoxic.

With regard to the tracheostomy procedure itself, complications occurred in two (4%) of the TLT patients. The most severe complication was noted in a 33-year-old woman with respiratory failure from septic shock due to bilateral empyema of the pleura caused by pneumococci. During intratracheal rotation of the tracheostomy tube the posterior tracheal wall was accidentally perforated. The tube was removed because the tube's correct position could not be confirmed bronchoscopically, ventilation via the tube was ineffective, and massive mediastinal and subcutaneous emphysema developed. The patient was immediately reintubated endotracheally, placing the endotracheal tube's end distal to the puncture site. Under these conditions, ventilation could be maintained, and aspiration of blood was prevented. Conventional surgical tracheostomy was performed by an ear-nose-throat surgeon who detected a 4 cm perforation of the posterior tracheal wall and severe damage to the second and third tracheal cartilage ring, which had to be resected. The emphysema resolved without adverse sequelae, and no further intervention was necessary.

In another patient on long-term ventilation due to low cardiac output failure after sinus valsalva aneurysm repair, the tracheostomy tube was pulled out a little too far and thus rotated not within the tracheal lumen but in the pretracheal soft tissues. Because the correct position of the tube could not be confirmed bronchoscopically, the procedure was aborted and PDT was performed.

Two (4%) severe complications were noted with the GWDF procedure. Massive bleeding (about 400 ml) from a previously undetected subcutaneous vein occurred in one patient and required substitution with coagulation factors (i.e., 2000 IU of prothrombin complex were administered). Another patient developed mediastinal emphysema 4 hours after uncomplicated GWDF that resolved spontaneously within the next 72 hours. In another nine patients minor bleeding (10–30 ml) was noted that did not require transfusion or further surgical intervention and thus was not considered a complication (Table 3).

Discussion

Elective tracheostomy in patients on long-term ventilation has become widely recognized as the airway management of choice. Conventional surgical tracheostomy was the most common pro-

Table 2. Operating times and oxygenation variables in patients who underwent elective percutaneous tracheostomy.

Parameter	TLT ($n = 50$) Preoperative	TLT ($n = 50$) Postoperative	GWDF ($n = 50$) Preoperative	GWDF ($n = 50$) Postoperative
Procedure time (min)	9.2 ± 3.9 (4.0–30.0)*		4.8 ± 3.7 (0.5–15.0)*	
FiO_2	0.52 ± 0.18** (0.21–1.0)	0.62 ± 0.21** (0.3–1.0)	0.58 ± 0.21 (0.30–1.0)	0.63 ± 0.26 (0.30–1.0)
PaO_2 (mmHg)	104.3 ± 26.8 (64.5–210.0)	103.7 ± 29.3 (66.0–219.1)	100.1 ± 22.0 (67.0–171.3)	94.5 ± 26.9 (51.0–207.5)
PaO_2/FiO_2 ratio	222.9 ± 95.9 (96.7–485.2)	194.9 ± 107.3 (66.0–547.8)	193.7 ± 74.4 (67.0–368.7)	175.8 ± 83.0 (51.0–366.7)

FiO_2: fraction of inspired oxygen; PaO_2: arterial oxygen tension.
Data are presented as the mean ± SD (range).
*$p < 0.05$ for TLT versus GWDF.
**$p < 0.05$ for preoperative versus postoperative values.

Table 3. Severe complications during percutaneous tracheostomy procedures.

Age (years)	Gender	Procedure	Indication for tracheostomy (diagnosis at ICU admission)	Complication
33	F	TLT	Septic shock (bilateral pleura empyema)	Posterior tracheal wall perforation →Emergency conversion to conventional tracheostomy
26	M	TLT	Low-output syndrome (congenital heart failure repair)	Pretracheal cannula placement →Emergency conversion to PDT
72	M	GWDF	Respiratory failure (coronary artery bypass grafting)	Mediastinal emphysema →Resolved spontaneously after 72 hours
64	F	GWDF	Septic shock (aortic valve replacement)	Massive bleeding (400 ml) →Administration of coagulation factors required

PDT: percutaneous dilatational tracheostomy; ICU: intensive care unit; →: consequence or follow-up of the respective complication.

cedure until the mid-1980s, but nowadays a number of minimally invasive techniques for tracheostomy are available and are considered safe, attractive alternatives to surgical tracheostomy [8–11]. According to Ciaglia and colleagues PDT is the most common percutaneous procedure and has already been widely investigated [9–11, 13–15]. TLT and GWDF are relatively new techniques or have not been investigated in large clinical trials or compared to each other in terms of practicability and perioperative complications.

Regardless of the fact that tracheostomy has become relatively safe, any tracheostomy procedure represents a potential risk for critically ill patients. The tracheostomy itself is associated with a number of severe complications, such as airway loss and hypoxia, bleeding, posterior tracheal wall traumatization, pneumothorax, and even death [10, 13, 16, 17]. Furthermore, when surgical tracheostomy is to be performed, many surgeons prefer that it be done in the operating room, where the patient must be transported from the ICU [18]. Minimally invasive techniques, as described by Griggs et al. and Fantoni and Ripamonti, are procedures that can be performed at the patient's bedside without a need for extensive preparations. The risks related to a critically ill patient's transport can be eliminated, and scheduling of the procedure is simplified.

The time required to perform conventional tracheostomy is reportedly about 20 to 45 minutes, not including transportation [10, 11, 14, 15]. In contrast, both TLT and GWDF require much less time and are less invasive. Especially in patients with severe respiratory failure due to ARDS or septic shock, any airway manipulation should be kept as short as possible. Our results show that even short manipulations worsen oxygenation. During TLT the postoperatively required FiO_2 was significantly higher than the preoperative baseline concentration, whereas GWDF did not affect oxygenation in any considerable manner. Despite these changes, the PaO_2/FiO_2 ratio, which represents a suitable means for evaluating overall oxygenation, remained almost unchanged, regardless of whether TLT or GWDF was done. Nonetheless, the preoperative FiO_2 allows the physician to counteract an eventual decrease of the arterial oxygen tension by increasing the inspired oxygen concentration. Therefore it is recommended that minimally invasive techniques not be employed in patients whose preoperative FiO_2 exceeds 0.6 to 0.8 or whose baseline PaO_2/FiO_2 ratio is below 100 to avoid hypoxia and associated mortality during the procedure [15, 19].

When the risks and benefits of elective tracheostomy are considered carefully, we believe that a skilled team may perform GWDF or TLT in patients whose respiratory condition is beyond the recommended limits. This statement can be attributed to some advantages of these techniques. In well trained hands, GWDF can be performed rapidly, so airway compromise is reduced to a minimum. During TLT continuous ventilation can be maintained via the thin endotracheal tube. In the recent study, two patients on 100% oxygen underwent either TLT or GWDF. No significant perioperative alteration of the PaO_2/FiO_2 ratio was noted.

Severe coagulopathy is often noted in critically ill patients and may limit the feasibility of surgical procedures. The prothrombin time was significantly prolonged in the GWDF group compared to that in the TLT group. Regardless of the fact that this parameter was worse than during TLT, it was still within an acceptable limit to allow safe surgery. Nonetheless, minor bleeding was noted in nine patients during GWDF. In contrast, progressive dilation of the tissues and trachea is unnecessary with the TLT technique, and the tracheostomy tube is pulled from inside the trachea to the outside at once without previous dilation. Thus the tracheostomy tube fits tightly against the wound edges, and any eventual bleeding tamponades itself. No remarkable bleeding was noted to the outside or the inside when TLT was performed. Furthermore, TLT was done in two patients with preexisting hemophilia A, in one of whom it was complicated by factor VIII inhibitors. After introducing the guidewire and removing the needle, only minimal bleeding was noted at the puncture site, and it ceased once the tracheostomy tube was in place. On the basis of our data, we conclude that TLT should be chosen instead of GWDF for patients with increased risk for intraoperative bleeding.

To avoid severe complications and associated morbidity or even death throughout the procedure, some precautions must strictly be obeyed when percutaneous tracheostomy is performed. Because the endotracheal tube must be changed during TLT, this technique must not be employed in patients with known or anticipated difficulties regarding endotracheal intubation, and physicians who perform TLT should be experts in intubation. Furthermore, enteral feeding should be stopped a few hours in advance to minimize the risk of aspiration or regurgitation. Regardless of the fact that GWDF can be performed rapidly, it must be emphasized that this technique should not be used to establish emergency airway access [19, 20]. When performed under emergency conditions and without bronchoscopic control, accidental traumatization of the posterior tracheal structures occurred in two of five animals in an experimental study, even though the physicians were well trained in the performance of GWDF [20]. These results give strong evidence that any percutaneous tracheostomy should be accompanied by fiberoptic bronchoscopic control. Through routine use of a bronchoscope, the trachea can be punctured under safe and visually confirmed conditions. If done "blind," the incidence of paramedian puncture of the trachea is reportedly as high as 45% [21]. Because such paramedian needle placement markedly increases the risk of paratracheal placement of the tracheostomy tube, we believe that bronchoscopic guidance must be routine throughout any percutaneous tracheostomy. Furthermore, eventual bleeding from the posterior tracheal wall can be recognized immediately, and secretions can be suctioned off via the bronchoscope. Nevertheless, minimally invasive tracheostomies may be associated with massive bleeding or accidental injuries that sometimes require immediate surgical intervention. Therefore TLT and GWDF should be performed only by physicians who, by virtue of their experience and training, are either able to master any eventual surgical complication or who can be sure that an experienced surgeon will be present within a few moments [15, 19].

Both TLT and GWDF are attractive alternatives to both conventional tracheostomy and PDT. They do not compromise oxygenation in a significant manner and therefore seem to be feasible even in patients with severe respiratory failure. Furthermore, the TLT technique of one-step dilation virtually eliminates the risk of perioperative bleeding. Even though TLT is much more difficult to learn and to perform than GWDF, it bears significant benefit for highly unstable patients. If certain precautions are carefully observed, TLT and GWDF can be considered safe, unlikely to result in major complications, and will prove their superiority to conventional tracheostomy.

Résumé

Buts: La trachéotomie élective est considérée partout comme une prise en charge idéale des patients sous ventilation prolongée. En dehors de la trachéotomie par voie ouverte, un certain nombre de procédés percutanés ont été introduits pendant les deux dernières décennies, et parmi eux, les techniques de Griggs (GWDF) et de Fantoni (TLT). Le but de cette étude a été d'évaluer ces deux techniques en termes de complications périopératoires, de risques et de bénéficies pour les patients enétat grave. Méthodes: 100 patients sévèrement malades, ventilés au long cours, ont eu une trachéotomie percutanée élective selon la technique GWDF (n = 50) ou TLT (n = 50). La trachéotomie a été réalisée sous anesthésie générale au lit du patient. Résultats: Les temps opératoires moyens ont été courts (9,2 ± 3,9 (TLT) vs 4,8 ± 3,7 (GWDF) minutes. Des complications périopératoires ont été notées chez 4% des patients, que ce soit pendant la TLT ou la GWDF, y compris l'hémorragie massive, l'emphysème médiastinal, les lésions de la paroi postérieure de la trachée et mauvais positionnement prétrachéal de la sonde de trachéotomie. Eu égard à l'oxygénation pré et postopératoire, les rapports PaO2/FiO2 n'ont pas varié de façon signifcative et on n'a noté aucune hypoxie périopératoire quel que soit le traitement employé. Conclusion: La TLT aussi bien que la GWDF, lorsqu'elles sont réalisées avec soin par des médecins expérimentés et sous contrôle bronchoscopique, sont des alternatives attractives et sures à la trachéotomie conventionnelle ou à d'autres procédés percutanés.

Resumen

En pacientes que han de ser ventilados durante largo tiempo, la traqueostomía electiva constituye la técnica más utilizada para el tratamiento de las vías aéreas. En las últimas dos décadas junto a la traqueostomía abierta se han empleado diversos procedimientos percutáneos entre ellos, las técnicas de Griggs (GWDF) y Fantoni (TLT). La finalidad del estudio fue evalular ambas técnicas en pacientes en estado crítico, por lo que a las complicaciones perioperatorias, riesgo y beneficios se refiere. Métodos: 100 pacientes adultos, en estado crítico, que requerían ventilación asistida durante largo tiempo fueron sometidos a traqueostomía electiva percutánea seqún la técnia de Griggs (n = 50) o de Fantoni (n = 50). La traqueostomia se realizó bajo anesthesia general en la misma cama de los pacientes. Resultados: La duración media de la intervención fue corta (9.2 ± 3.9) para la TLT y 4.8 ± 3.7 minuotos para la GWDF. Se observaron, tanto con una técnica como con la otra, un 4% de complicaciones perioperatorias que incluyeron: hemorragias masivas, enfisemea mediastínico, lesiones de la pared posterior de la traquea y colocación pretraqueal del tubo de traqueostomía. Por lo que a la oxigenación se refiere los cocientes PaO_2/FiO_2 no se modificaron de forma signifcativa entre el pre y postoperatorio, no registrándose hipoxia perioperatoria con ninguno de ambos procedimientos. Conclusión: Tanto la TLT como la GWDF constituyen alternativas atractivas y fiables a la traqueostomía convencional o a otros procedimientos percutáneos, siempre y cuando la intervención se realice cuidadosamente, por médicos expertos y bajo control bronchoscópico.

References

1. Heffner, J.E., Miller, K.S., Sahn, S.A.: Tracheostomy in the intensive care unit. Part 1. Indications, technique, management. Chest *90*:269, 1986
2. Lesnik, I., Rappaport, W., Fulginiti, J., Witzke, D.: The role of early tracheostomy in blunt, multiple trauma. Am. Surg. *58*:346, 1992
3. Rodriguez, J.L., Steinberg, S.M., Luchetti, F.A., Gibbons, K.J., Taheri, A., Flint, K.M.: Early tracheostomy for primary airway control in the surgical critical care setting. Surgery *108*:655, 1990
4. Toye, F.J., Weinstein, J.D.: A percutaneous tracheostomy device. Surgery *65*:384, 1969
5. Ciaglia, P., Firsching, R., Syniec, C.: Elective percutaneous dilatational tracheostomy: a new simple bedside procedure; preliminary report. Chest *87*:715, 1985
6. Schachner, A., Ovil, Y., Sidi, J., Rogev, M., Heilbronn, Y., Levy, M.: Percutaneous tracheostomy: a new method. Crit. Care Med. *17*:1052, 1989
7. Griggs, W.M., Worthley, L.I.G., Gilligan, J.E., Thomas, P.D., Myburgh, J.A.: A simple percutaneous tracheostomy technique. Surg. Gynecol. Obstet. *170*:543, 1990
8. Griggs, W.M., Myburgh, J.A., Worthley, L.I.G.: A prospective comparison of a percutaneous tracheostomy technique with standard surgical tracheostomy. Intensive Care Med. *17*:261, 1991
9. Graham, J.S., Mulloy, R.H., Sutherland, F.R., Rose, S.: Percutaneous versus open tracheostomy: a retrospective cohort outcome study. J. Trauma *42*:245, 1996
10. Holdgaard, H.O., Pedersen, J., Jensen, R.H., Outzen, K.E., Midtgaard, T., Johansen, L.V., Moller, J., Paaske, P.B.: Percutaneous dilatational tracheostomy versus conventional surgical tracheostomy. Acta Anaesthesiol. Scand. *42*:545, 1998
11. Stoeckli, S.J., Breitbach, T., Schmid, S.: A clinical and histological comparison of percutaneous dilational versus conventional surgical tracheostomy. Laryngoscope *107*:1643, 1997
12. Fantoni, A., Ripamonti, D.: A non-derivative, non-surgical tracheostomy: the translaryngeal method. Intensive Care Med. *23*:386, 1997
13. Wang, M.B., Berke, G.S., Ward, P.H., Calcaterra, T.C., Watts, D.: Early experience with percutaneous tracheostomy. Laryngoscope *102*: 157, 1992
14. McHenry, C.R., Raeburn, C.D., Lange, R.L., Priebe, P.P.: Percutaneous tracheostomy: a cost-effective alternative to standard open tracheostomy. Am. Surg. *63*:646, 1997
15. Westphal, K., Byhahn, C., Rinne, T., Wilke, H.J., Wimmer-Greinecker, G., Lischke, V.: Tracheostomy in cardiosurgical patients: surgical tracheostomy versus Ciaglia and Fantoni methods. Ann. Thorac. Surg. *68*:486, 1999
16. Douglas, W.E., Flabouris, A.: Surgical emphysema following percutaneous tracheostomy. Anaesth. Intensive Care *27*:69, 1999
17. Malthaner, R.A., Telang, H., Miller, J.D., McFadden, S., Inculet, R.I.: Percutaneous tracheostomy: is it really better? Chest. *114*:1771, 1998
18. Stock, M.C., Woodward, C.G., Shaprio, B.A., Cane, R.D., Lewis, V., Pecaro, B.: Perioperative complications of elective tracheostomy in critically ill patients. Crit. Care Med. *14*:861, 1986
19. Bause, H., Prause, A., Schulte am Esch, J.: Indication and technique of percutaneous dilatation tracheostomy for the intensive care patient. Anaesthesiol. Intensivemed. Notfallmed. Schmerzther. *30*:492, 1995
20. McLure, H.A., Dob, D.P., Mannan, M.M., Soni, N.: A laboratory comparison of two techniques of emergency percutaneous tracheostomy. Anaesthesia *52*:1199, 1997
21. Dexter, T.J.: A cadaver study appraising accuracy of blind placement of percutaneous tracheostomy. Anaesthesia *50*:863, 1995