Chapter 10
Complications of Percutaneous and Surgical Tracheostomy in Critically Ill Patients

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Abstract Percutaneous tracheostomy is more widely used in intensive care unit. In critical patients, it has many potential advantages over endotracheal intubation including reduction of respiratory resistance, work of breathing, length of mechanical ventilation, laryngeal injury and a better clearance of airway secretions. From a practical point of view, percutaneous tracheostomy is a safe and cost-effective technique performed at bedside, but it is not without risks and complications. The reported incidence of significant complications for PDT is about 1–10 %, including both short-term and long-term complications.

Percutaneous tracheostomy is more widely used in intensive care unit. Different percutaneous tracheostomy techniques have been proposed: (1) single-step dilatational techniques [Ciaglia Blue Rhino (CBR), Ciaglia Blue Dolphin (CBD), PercuTwist (PT)], (2) multiple step dilatational technique [Ciaglia multiple dilator], (3) guide wire dilating forceps technique [Griggs technique – GWDF] and (4) retrograde translaryngeal tracheostomy [Fantoni technique – TLT]. In critical patients, it has many potential advantages over endotracheal intubation including reduction of respiratory resistance, work of breathing, length of mechanical ventilation, laryngeal injury and a better clearance of airway secretions [1, 2]. Furthermore, tracheostomy has been reported to reduce the need of sedation, to improve patient comfort and communication as well as to facilitate nursing work. From a practical point of view, percutaneous tracheostomy is a safe and cost-effective technique performed at bedside, but it is not without risks and complications [3]. The reported incidence of significant complications for PDT is about 1–10 %, including both short-term (such as bleeding, loss of airway and infection) and long-term (tracheal stenosis, tracheomalacia, tracheocutaneous fistula and so forth) complications. Many of these complications are potentially

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preventable and may be related to technical and procedural factors. Attention to the level of placement may have an impact on the risk of tracheal stenosis, trachea-innominate fistula and dislodgment [4]. Selection of the appropriate tube size and puncture site may decrease the risk of early dislodgement [4]. Avoidance of vascular structures may decrease the risk of bleeding [4]. Accurate assessment of endotracheal tube (ETT) tip position may decrease the risk of airway loss [4]. These procedural considerations may be particularly relevant in patients with high-risk factors, which may increase the technical difficulty of the procedure and the risk of complications. These high-risk factors include coagulopathy, morbid obesity, cervical spine immobilisation (CSI), repeat tracheostomy and the ongoing need for high levels of respiratory support. Most of the literature consists of observational data or small prospective studies; therefore debate still continues as to which method is preferred. Early complications of tracheostomy include bleeding, wound infection, false route or early tube displacement, subcutaneous emphysema and pneumothorax [5]. Late complications include swallowing problem, tracheal stenosis, tracheo-innominate artery fistula [5]. In the literature, there is no agreement on the definition of complications. Some authors divided complications in: (1) early or late complications if they occur, respectively, within or a week after tracheostomy placement; (2) perioperative or postoperative complications if they occur during the first 24 h or after 24 h from the procedure [6], in addition to intraoperative complications; and (3) minor and major complications. Minor complications are defined as clinically irrelevant when no patient harm occurred, while major complications were classified as potentially life threatening or with the need of an intervention. According to different tracheostomy techniques developed during the last 30 years, many published studies compared different percutaneous tracheostomies to each other or to surgical procedures. Four meta-analysis compared surgical to percutaneous multiple and/or single dilatational tracheostomy (PDT). In 1999, Dulgerov et al. performed a meta-analysis to compare percutaneous tracheostomy technique, introduced in 1985, with a historical control group of surgical tracheostomy performed from 1960 to 1996 [7]. In this study, 55 randomised clinical trials were included; perioperative and postoperative complications were further subdivided in serious, intermediate and minor subgroups according to the severity. Percutaneous technique was associated with more perioperative but less postoperative complications than surgical tracheostomy. Another meta-analysis of prospective clinical trials to compare PDT and surgical technique in critically ill patients was performed by Freeman et al. including 5 studies and 236 patients [8]. In this study, PDT showed advantages compared to ST including ease of performance, lower incidence of peristomal bleeding and postoperative infection [8]. In 2006, Delaney et al. performed a systematic review and meta-analysis comparing PDT and surgical tracheostomy, to investigate the possible differences in the incidence of wound infection, bleeding, perioperative and long-term complications as well as mortality [9]. Seventeen randomised clinical trials,

published between 1996 and 2005 involving 1212 ICU patients, were eligible for this meta-analysis. Clinically important wound infection occurred in 6.6 % of patients; PDT was associated to less infection compared to surgical tracheostomy. Overall incidence of bleeding was 5.7 %, mortality rate 37 % and major complications 2.6 % with no statistical difference in the subgroup analysis. These results showed that PDT was associated to a reduction of infection and was equivalent to surgical tracheostomy in the mortality and perioperative and long-term complications [5]. Higgins and Punthake performed another meta-analysis to compare complications rates of PDT versus surgical tracheostomy in mechanically ventilated patients involving 15 RCTs including 973 patients [10]. Pooled analysis revealed infection, unfavourable scarring and overall trend of complications, but no difference in false passage, minor haemorrhage, major haemorrhage and subglottic stenosis [10]. Information regarding long-term complications of surgical or percutaneous tracheostomy are astonishingly scanty. This is likely due to difficulties to monitor patients who underwent tracheostomy because of high mortality and poor neurological outcome and patient collaboration which makes difficult planned post-procedural evaluation. In 2005, Antonelli et al. in a randomised clinical trial with 1-year double-blind follow-up assessed short-term and long-term complications of translaryngeal tracheostomy (TLT) and surgical technique [11]. One hundred and thirty-nine patients were enrolled, 67 in TLT group and 72 in the surgical technique group, but only 31 patients were contacted for the follow-up. TLT showed many advantages compared to surgical technique, it was more rapid and associated to less perioperative bleeding, but infection complications and bacteraemia were similar between the groups. Follow-up evaluation showed that stomatoplasty or evident tracheal stenosis occurred more frequently in the surgical group, but quality of life didn't differ between them [11]. Among long-term complications, tracheal stenosis is the most serious and life threatening. Raughuraman found that tracheal stenosis caused by PDT was significantly closer to the vocal cord and associated with early onset and with more difficult surgical correction compared to surgical technique [12]. While there is support in the literature of equivalent early complication rates between open and percutaneous techniques, there is less evidence about their equivalency with regard to late complications such as tracheal stenosis. For this reason, there is still debate about which method provides superior patient outcomes. The incidence of symptomatic tracheal stenosis following OT or PT ranges in the literature from 0 to 10 %. The true incidence of tracheal stenosis is difficult to ascertain because it is often subclinical in nature. Kettunen et al. in 2014 compared incidence of, and factors contributing to, tracheal stenosis following percutaneous tracheostomy (PT) or open tracheostomy (OT). Of 616 patients, 265 underwent OT and 351 underwent PT. Median injury severity score was higher for PT (26 vs. 24, *P* 5.010) [13]. Overall complication rate was not different (PT 52.3 % vs. OT5 2.6 %, *P* 5.773). There were nine tracheal stenosis, four (1.1 %) from the PT group and five (1.9 %) from the OT group (*P* 5.509). Mortality was higher in OT

patients (15.5 % vs. 9.7 %, *P* 5.030). Numerous and variable risk factors for tracheal stenosis following intubation have been suggested in the literature and include trauma and inflammation at the endotracheal tube cuff site, excess granulation tissue around the tracheal stoma site or over a fractured cartilage, high tracheostomy site, prolonged intubation, traumatic intubation or previous intubation or tracheostomy [13]. The authors demonstrated that patients who developed tracheal stenosis tended to have longer mechanical ventilator requirements (26.7 vs. 16.1 days, *P* 5.055), with patients developing stenosis being on the ventilator on average 11 additional days [13]. It could be hypothesised that additional ventilator days meant more time with an inflated tracheal cuff causing tracheal ischemia and stenosis. They did identify that younger age and longer length of ICU stay were associated with increased rate of tracheal stenosis; however, the reason for these findings is unclear, and these findings were not observed in similar studies [13]. Other studies compared different percutaneous techniques to each other. Divisi et al. in a retrospective study reported similar complication rates in TLT and CBR [14], but the latter was associated with fewer iatrogenic complications, less procedural time and less complex execution [14]. In a prospective randomised clinical trial, Cianchi et al. compared Ciaglia Blue Rhino with Ciaglia Blue Dolphin tracheostomy in ICU. Seventy patients with no difference in baseline characteristics were enrolled, 35 assigned to CBR group and 35 to CBD group. CBD was more frequently associated to a presence of blood drain on tracheal and bronchial mucosa, tracheal ring buckling and injury, cutaneous bleeding and resistance to tracheal tube passage [15]. Fikkers et al. compared single-step dilatational tracheostomy versus (SSDT) guide wire dilating forceps technique (GWDF) in a randomised clinical trial involving 120 patients [6]. Overall complications were higher in the GWDF than in SSDT, in particular, minor or major blood loss, difficult cannula insertion and difficult dilation, and conversions in another technique were more frequent in the guide wire forceps technique [6]. GWDF was compared with PercuTwist (PT) in a prospective randomised trial by Montcriol et al. In this study 87 patients were enrolled, 45 randomised in PT group and 42 in the GWDF group [16]. Whereas there was no statistical difference in complications, the authors identified two trends. Griggs technique was associated to more bleeding complication due to its dilatational procedure; probably in PT the rotational dilatation with the screw provided a tight closure of the stoma. The second trend concerned cannulation difficulties, because PT technique required a more physical strength for a complete dilation so cannula placement is often difficult [16]. Different percutaneous tracheostomies result in a different pattern of complications due to the main practical features of the technique. Cabrini et al. performed a meta-analysis of randomised clinical studies to evaluate if one PDT technique is superior to another with regard to minor and major intraprocedural complications [17]. Thirteen randomised clinical studies were finally included in the review involving 1030 patients and six techniques. The main result of this study was that GWDF, SSDT

and multiple dilatational techniques were equivalent in safety, and SSDT was superior to GWDF for mild complications. In 2014 Putensen et al. conduct a meta-analysis to determine whether PT techniques are advantageous over ST and if one PT technique is superior to the others [18]. Computerised databases (1966–2013) were searched for randomised controlled trials (RCTs) reporting complications as predefined endpoints and comparing PT and ST and among the different PT techniques in mechanically ventilated adult critically ill patients [18]. According to the authors, available evidence from RCTs including adult critically ill patients tends to show that PT techniques are performed faster and reduce stoma inflammation and infection but are associated with increased technical difficulties when compared with ST. Among PT techniques, MDT + SSDT are associated with the lowest odds for intraprocedural technical difficulties and major bleeding, while GWDF accounts for increased odds for intraprocedural major bleeding [18].

While bronchoscopic guidance is routinely used during PDT, bedside ultrasound has, more recently, received attention as a potentially useful tool to improve the safety of PDT. The potential advantages of US include the ability to identify the cervical vasculature [4], assist with tube size and length selection [19], help identify the most appropriate location for the tracheal puncture site and guide needle insertion into the trachea. Several studies have demonstrated the value of preprocedural cervical US to improve the safety of PDT [12, 20, 21]. In 1999, the first real-time US-guided PDT was described [22], followed by the publication of several reports, including a systematic review [23–26]. Preprocedural assessment with ultrasound was described several years ago, as was the use of ultrasound during the procedure to facilitate tracheal puncture at the appropriate level, without real-time visualisation of needle passage [12, 20, 27, 28]. Rajajee et al. in 2015 reviewed all percutaneous dilatational tracheostomies performed in an 8-year period in a neurocritical care unit [4]. Bronchoscopic guidance was used for all procedures with addition of real-time ultrasound guidance at the discretion of the attending physician. Real-time ultrasound guidance was used to guide endotracheal tube withdrawal, guide tracheal puncture, identify guide wire entry level and confirm bilateral lung sliding. The primary outcome was a composite of previously defined complications including (among others) bleeding, infection, loss of airway, inability to complete procedure, need for revision, granuloma and early dislodgement [4]. Propensity score analysis was used to ensure that the relationship of not using real-time ultrasound guidance (RUSG) with the probability of an adverse outcome was examined within groups of patients having similar covariate profiles [4]. A total of 200 patients underwent percutaneous dilatational tracheostomy during the specified period, and 107 received real-time ultrasound guidance. Risk factors for percutaneous dilatational tracheostomy were present in 63 (32 %). There were nine complications in the group without real-time ultrasound guidance: bleeding ($n = 4$), need for revision related to inability to ventilate or dislodgement ($n = 3$) and symp-

tomatic granuloma ($n = 2$) [4]. There was one complication in the real-time ultrasound guidance group (early dislodgement) [4]. The odds of having an adverse outcome for patients receiving real-time ultrasound guidance were significantly lower (odds ratio = 0.08; 95 % confidence interval, 0.009–0.811; $P = 0.032$) than for those receiving a standard technique while holding the propensity score quartile fixed [4]. In this study the use of RUSG during PDT was associated with a significantly lower rate of procedure-related complications in a propensity score-matched analysis and may be particularly useful when performing PDT in patients with risk factors, such as coagulopathy [4]. Gobatto et al. in 2015 analysed all patients who were submitted to PDT after the standardisation of US-guided PDT technique in their institution [29]. Sixty patients who had been submitted to PDT were studied, including 11 under bronchoscopy guidance and 49 under US guidance. No surgical conversion was necessary in any of the procedures, and bronchoscopy assistance was only required in one case in the US group. The procedure length was shorter in the US group than in the bronchoscopy group (12 vs. 15 min, $P = .028$). None of the patients had any major complications. The minor complication rates were not significantly different between the groups nor was the probability of breathing without assistance within 28 days, intensive care unit length of stay or hospital mortality. In this study ultrasound-guided PDT is effective, safe and associated with similar complication rates and clinical outcomes compared with bronchoscopy-guided PD [29]. In the same way Ravi et al. evaluate the efficacy of ultrasound-guided percutaneous tracheostomy (USPCT) and bronchoscopic-guided percutaneous tracheostomy (BPCT) and the incidence of complications in critically ill, obese patients [30]. Seventy-four consecutive patients were included in a prospective study and randomly divided into USPCT and BPCT. The overall complication rate was higher in BPCT than USPCT patient group (75 % vs. 321 %, $P < 0.05$). Most complications were minor (hypotension, desaturation, tracheal cuff puncture and minor bleeding) and of higher number in the BPCT. Ultrasound-guided PCT was possible in all enrolled patients, and there were no surgical conversions or deaths. Real US-guided PCT is a favourable alternative to BPCT with a low complication rate and ease, thus proving more efficacious [30].

In conclusion, in critically ill patients: (1) percutaneous might be considered as the technique of choice for tracheostomy performed in ICU. Surgical tracheostomy should be reserved for patients when percutaneous tracheostomy is contraindicated. (2) Among different percutaneous dilatational techniques, single-step dilatational tracheostomy was easy and safe to perform and associated to less complication than the other techniques. Minor bleeding is the most common complication with the Griggs technique, while puncture of endotracheal tube, cannula displacement or difficult dilatations are more frequently observed with the other commonly percutaneous tracheostomy techniques (Table 10.1).

Table 10.1 Meta-analyses on PDT in critically ill patients

Author, year [ref]	Number of studies	Type of included studies	Population	Searching strategy until (years)	Statistical analysis	Number of patients	Main outcome	Conclusions
Dulguerov et al. (1999) [7]	65 articles	RCT, PT, RT	ST vs. PT	1960–1984 1985–1996	No OR, RR or RD calculated	9514	Serious complications: death, cardiopulmonary arrest, pneumothorax, pneumomediastinum, tracheoesophageal fistula, mediastinitis, sepsis, intratracheal postoperative haemorrhage, cannula obstruction and displacement, tracheal stenosis Intermediate complications: intraoperative desaturation, lesions of the posterior tracheal wall, cannula misplacement, switch of a PT procedure to a surgical technique, aspiration pneumonia, atelectasis, lesion of the tracheal cartilages Mild complications: intraoperative haemorrhage, false passage, difficulty with tube placement, subcutaneous emphysema, postoperative wound haemorrhage, infections, delayed closure of tracheostomy tract, keloids, unaesthetic scarring	Higher incidence of perioperative complications, perioperative death and serious cardiorespiratory events in the PT group Higher incidence of postoperative complications in ST group

(continued)

Table 10.1 (continued)

Author, year [ref]	Number of studies	Type of included studies	Population	Searching strategy until (years)	Statistical analysis	Number of patients	Main outcome	Conclusions
Freeman et al. (2000) [8]	5 articles	PT	MDT vs. ST	1985–2000	MD; OR	236	Length of procedure; operative complications; intraoperative bleeding; postoperative complications; postoperative bleeding; stoma infection; mortality	PT shorter length and greater ease of procedure PT lower incidence of overall postoperative complications, intraprocedural and post-procedural bleeding and stoma infections
Delaney. et al. (2006) [9]	17 articles	RCT	PT vs. ST	Inception to 2005	OR	1.212	Wound infection, bleeding, mortality	Compared with ST, PT has a lower incidence of wound infections Compared with ST, PT is not associated with a higher incidence of clinically significant bleeding, major periprocedural or long-term outcomes When comparing open ST performed in the ICU, PT has a lower incidence of relevant bleeding

Higgins and Punthake (2007) [10]	368 abstracts; 15 articles	RCT	PT vs. ST	1991–2005	OR	973	Minor haemorrhage; major haemorrhage; false passage; wound infection; unfavourable scar; decannulation/dislodgment; subglottic stenosis; mortality	PT higher incidence of false passage and accidental decannulation PT lower incidence of wound infection and unfavourable scarring PT performed faster and with more cost effectiveness Overall complications did not differ between groups When comparing open TT performed in the OT vs. PT performed in the ICU, PT has a lower overall complication rate
Cabrini et al. (2012) [17]	13	RCT	Within PT	2000–2010	RD	1130	Conversion to other method; any mild complications; any severe complications	SSDT lower incidence of mild complications than BDT and GWDF SSDT lower frequency of failure than RDT GWDF lower incidence of severe complications and frequency of failure than TLT No differences between MDT and SSDT MDT lower incidence of mild complications than GWDF, same incidence of severe complications and conversion rate

(continued)

Table 10.1 (continued)

Author, year [ref]	Number of studies	Type of included studies	Population	Searching strategy until (years)	Statistical analysis	Number of patients	Main outcome	Conclusions
Putensen et al. (2014) [18]	14	RCT	PT vs. ST; within PT	1966–2013	OR	973	Complications during the procedure: major and minor bleeding, technical difficulties, false route, subcutaneous emphysema, pneumothorax and oxygen desaturation Complication after the procedure: major and minor bleeding, stoma inflammation or infection, tracheomalacia and tracheal stenosis	PT techniques are performed faster and reduce stoma inflammation and infection PT are associated with increased technical difficulties when compared with ST MDT + SSDT are associated with the lowest risk for intraprocedural technical difficulties and major bleeding GWDF is associated with increased risk for intraprocedural major bleeding

RCT randomised controlled trials, *PT* prospective trials, *RT* retrospective trial, *ST* surgical tracheostomy, *PT* percutaneous tracheostomy, *OR* odds ratio, *RR* relative risk, *RD* risk difference, *MD* weighted mean difference, *OT* operating theatre, *TT* tracheostomy, *MDT* multiple dilatation tracheostomy, *SSDT* single-step dilatation tracheostomy, *GWDF* guide wire dilating forceps, *BDT* balloon dilatation tracheostomy, *RDT* rotational dilation tracheostomy

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