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Percutaneous Tracheostomy on the Intensive Care Unit

Bernard G. Fikkers

"Percutaneous Tracheostomy on the Intensive Care Unit"
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Thesis Radboud Universiteit Nijmegen

Cover: Erwin Scholte. Detail of "The hay wagon", Hiëronymus Bosch (1450 – 1516), Madrid, Museo del Prado.
ISBN: 90-9018282-9

The contributions of COOK critical care, Maquet-Copharm, Smiths Medical BV, Endomed BV, Tyco Healthcare Nederland BV (Shiley), GlaxoSmithKline BV and Paes Nederland BV (Olympus) are gratefully acknowledged.

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Percutaneous Tracheostomy on the Intensive Care Unit

een wetenschappelijke proeve op het gebied van de
Medische Wetenschappen

Proefschrift

ter verkrijging van de graad van doctor
aan de Radboud Universiteit Nijmegen,
op gezag van de Rector Magnificus prof. dr. C.W.P.M. Blom,
volgens besluit van het College van Decanen
in het openbaar te verdedigen op donderdag 9 september 2004
des namiddags om 1.30 uur precies door

Bernardus Gerhardus Fikkers

geboren op 25 oktober 1961 te Groningen

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Contents

Chapter 1

Introduction and outline

This is a thesis on percutaneous tracheostomy in the intensive care unit (ICU). Since its introduction by Ciaglia in 1985, this technique has become a common procedure in ICUs around the world. In the medical literature, the majority of publications use the term 'percutaneous tracheostomy', and only a few 'percutaneous tracheotomy'. In this context, however, the terms 'percutaneous', 'tracheostomy' and 'tracheotomy' are semantically incorrect. 'Percutaneous' means 'through the skin'. This term is applicable to both techniques described in this thesis as well as to surgical tracheostomy. The suffix '-stomy' and '-stoma' means a mucocutaneous anastomosis. This is usually the case with the surgical technique, but not with the percutaneous technique. The suffix '-tomy' means access to a (hollow) space, in this case the trachea, with the aid of a (surgical) knife. Again, this is the case with the surgical, but not with the percutaneous technique. The conclusion must therefore be that the term 'percutaneous tracheostomy' is at least debatable. It would be more correct to talk about 'puncture tracheotomy', but this term was never popularised.

The aim of this thesis is to describe the practice of the most frequently used percutaneous tracheostomy techniques, to assess their safety profiles, both short- and long-term, to compare the most frequently used techniques, and to study in detail various serious adverse events.

Chapter 2 describes the history of tracheostomy from antiquity to the present day. Chapter 3 discusses a national survey on the use of tracheostomy. Chapter 4 explains the different dilational techniques available for making a tracheostoma, i.e. an artificial opening in the trachea. Short- and long-term complications are also discussed. Chapter 5 focuses on the role of bronchoscopy during the procedure. Some serious complications are analysed, including subcutaneous emphysema and pneumothorax. Chapter 6 describes the non-elective entrance to the trachea, the emergency

cricothyrodotomy. Finally, Chapter 7 gives an overview of the present literature, including the studies performed in this thesis. Peri- and post-operative complications are classified in a systematic and precise way.

Chapter 2

History of tracheostomy

Antiquity and Middle Ages

Tracheostomy is one of the oldest surgical procedures and was probably already used by the ancient Egyptians about 3500 years ago[1]. The fact that by simply opening the airway a suffocating person could be saved has always fascinated doctors. However, this procedure was considered very dangerous, because of the high mortality rate, and was therefore rarely performed. Before 1800, not more than 55 successful tracheostomies were recorded[1]. Tracheostomy on a sheep was described in the sacred book of Hindu medicine, the Rig Veda, which was written between 2000 and 1000 B.C.[2] Alexander the Great (356-323 B.C.) was among the first person who performed a tracheostomy on his own: 'he opened the trachea of a choking soldier with the point of his sword'. In the times of the Roman Empire, the technique was described on several occasions as a way to treat obstruction of the upper airways. Galen (130-200) credited Asclepiades of Bithynia from Rome (124-56 B.C.) with being the first surgeon to perform an elective tracheostomy. In the Byzantine times, operations on the trachea were performed quite regularly[3]. In his seven-part book *Epitome*, Paul of Aegina (625-690) meticulously described the technique of tracheostomy: 'In cases of inflammation of the mouth or palate, it is reasonable to use tracheostomy ("φαρυγγοτομια", pharyngotomy) in order to prevent suffocation. We cut the aspera artery (trachea) below the upper part of the trachea, at the level of the third or fourth ring. For a better exposure of the trachea, the head needs to be reclined. A transverse incision is made in between two tracheal rings, so it is not the cartilage that is incised, but the tissue in between'. Paul of Aegina commented on the lost work of the ancient Greek surgeon Antyllus (second century A.D.) and explained how one could tell whether the procedure had been a success (from the wheezing noise of air escaping from the hole in the trachea and from the loss of the patient's voice). In the fifth century, however, Caelius Aurelanius wrote: 'Laryngotomy is an unimportant and irresponsible idea introduced by Asclepiades'. In the next millennium, the procedure was not or rarely used.

In the 16th century, the operation was again performed and further developed. In 1546, the Italian surgeon Antonio Mousa Brasavola (1490-1554) was the first to perform a tracheostomy after an interlude of 1000 years. He saved the life of a patient who was about to die from suffocation due to a phlegmone of the floor of the mouth. He is quoted as having said, 'when there is no other possibility, in angina, of admitting air to the heart, we must incise the larynx below the abscess'[4]. The second person to perform the operation was the Italian anatomist and surgeon Hieronymus Fabricius of Aquapendente (1537-1619). In his book *Opera chirurgica*, he recommended a tracheostomy in cases of 'deviations of the mouth, under the chin, of the tonsils and of the throat and in cases of severe inflammation of the larynx, when the uvula obstructs the aspera arteria, leaving the bronchi uninvolved'. He described how the operation was performed with a median length-incision in the skin, an entrance to the trachea between the third and fourth tracheal rings, and, for the first time in history, with the aid of a cannula. This cannula was straight and short, so it did not touch the vulnerable posterior tracheal wall, and had two wings on the outside to prevent aspiration of the cannula. His student Julius Casserius (1545-1616) described the anatomy of the head and neck regions in his book *De vocalis auditusque organis historia anatomica*, in which he also included some illustrations of a tracheostomy. In one of those illustrations (Figure 1), a long fenestrated cannula can be seen[5].

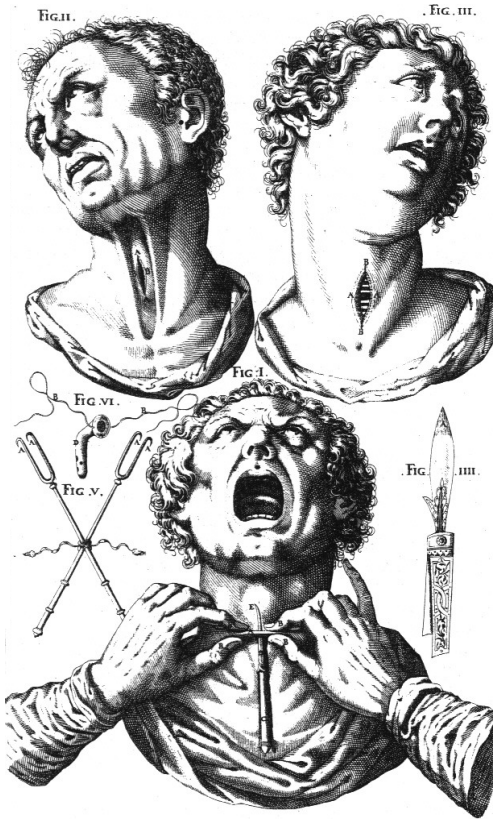

Figure 1. Tracheostomy ("*Laryngotomia*"), illustration in a book by Julius Casserius (1545-1616).

Because the surgical procedure was not without danger and certainly not painless, the Italian Sanctorio Sanctorius (1561-1636) developed a different technique in 1626: the percutaneous tracheostomy. In a simple manner, entrance to the trachea was made with a needle and a silver perforated cannula, and subsequently the needle was withdrawn[5]. In 1641, Nicolaas Fontanus, a surgeon from Amsterdam, also described a successful tracheostomy. He was called upon a patient who was thought to die within the next hours from angina. Although he had never seen a tracheostomy performed, he did the operation.

Although often only the incision of the trachea was described, terms like 'bronchotomy', 'laryngotomy' and 'pharyngotomy' were also used. Lorenz Heister (1683-1758), a German surgeon, who also performed struma surgery, introduced the term 'tracheostomy' in 1718. Hundred years later, tracheostomy was a generally accepted term. From that period dates the story about George Washington, first president of the United States. In 1799, at the age of 67 years, he was severely ill with a sore throat, dysphagia and dyspnoea. The cause was presumably a bacterial epiglottitis ('cynanche trachealis'), although historians do not all agree. One of his physicians advised a tracheostomy, but two others strongly disagreed. They proposed a more traditional treatment, a venous bleed. Washington died that same night, December 14th 1799, from suffocation, although a tracheostomy might have saved him[6].

Nineteenth century

In 1833, the French physician Pierre Fidèle Bretonneau (1778-1862) and his student Armand Trousseau (1801-1867) were the first to use tracheostomy on a routine basis, during an epidemic of diphtheria. The latter proudly presented his results: "Today, gentlemen, I have performed this operation more than 200 times and I am reasonably happy to have success in more than 25 percent of cases"[5]. This certainly was an improvement on previous results. Trousseau used a spreader to keep the trachea open during insertion of the cannula.

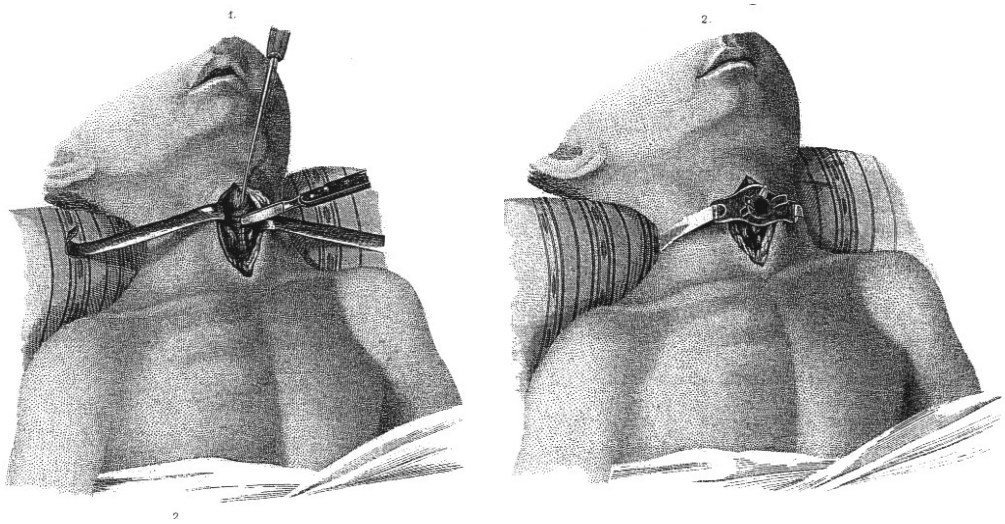

Figure 2. Tracheostomy in a child with diphtheria (with vertical skin incision)

Tracheostomy was now an accepted intervention for treating obstruction of the respiratory tract due to laryngeal trauma, a foreign body, goitre or infections (phlegmone of the floor of the mouth, diphtheria) and even for resuscitating people rescued from drowning.

Twentieth century

In the beginning of the twentieth century, there was a decline in the number of tracheostomies. Thanks to the work of the American paediatrician Joseph O'Dwyer (1841-1894), the orotracheal intubation was introduced as a treatment for obstruction of the higher airways. His studies revealed a better survival rate after orotracheal intubation compared to tracheostomy in the treatment of diphtheria and croup. In 1909, Chevalier Jackson (1865-1958) systematised the approach to tracheostomy and clarified the important principles of its performance[7]. He emphasised the importance of oxygenation and control of the patient's airway. He insisted that the hypoxic patient should not be anesthetised. In addition, he emphasised the importance of post-operative care. Since centuries, tracheostomy was only used for the relief of upper airway obstruction, but since the beginning of the twentieth century the procedure was

also used for bronchial toilet. The third indication for tracheostomy, artificial ventilation, was introduced in 1952, during the polio epidemic in Copenhagen[8]. With tracheostomy intermittent positive pressure ventilation was possible, which facilitated weaning from mechanical ventilation compared to an endotracheal tube. It became apparent that a tracheal cannula decreased the dead space, did not harm the vocal cords and was accepted more easily than an endotracheal tube by non-sedated patients. After this experience, the indications for using a tracheostomy were expanded to include, for example, neurological diseases such as multiple sclerosis and syringobulbia. At present, about 80% of tracheostomies are performed for pathology of the lower airways in patients who cannot breath independently[9].

The percutaneous tracheostomy

In 1955, Shelden introduced the first modern percutaneous tracheostomy set[10]. It consisted of a cannula over the needle, resembling the cannula used by Sanctorius in the 16th century. However, multiple deaths were reported secondary to the trocar's laceration of vital structures adjacent to the airway[11,12]. Twelve years later, thanks to Toye and Weinstein, the Seldinger technique became available. Through a hollow needle, a guide wire was threaded into the trachea. Subsequently, the cannula was introduced over the guide wire[13]. It was further improved[14], until the American surgeon Pasquale Ciaglia (1912-2000), who had observed radiologists performing dilational nephrostomies[15], described a brandnew variant of this technique in 1985: the Progressive Dilational Tracheostomy (PDT). Over a guide wire, progressively wider dilators were introduced.

Nowadays, there are several different percutaneous tracheostomy techniques. Schachner et al.[16] and Griggs et al.[17] described, in 1989 and 1990 respectively, two variants of the percutaneous tracheostomy technique: the Rapitrac technique and the Guide Wire Dilating Forceps (GWDF) technique. Both techniques are based on a specifically designed instrument to dilate the trachea in several steps. A further refinement of the technique came in 1999, when the Ciaglia Blue Rhino became available. This is a single dilator technique, using a conic dilator. The GWDF and Blue Rhino are the techniques most frequently used in the intensive care unit [18].

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Chapter 3

Tracheostomy for long-term ventilated patients: a postal survey of ICU practice in the Netherlands

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Intensive Care Medicine 2003 ;29: 1390-1393

Abstract

Objective: To assess the frequency, timing, technique and follow-up of tracheostomy for long-term ventilated patients in different intensive care units (ICUs) in the Netherlands.

Design: Postal questionnaire, survey on retrospective data.

Setting: A questionnaire was sent to all (*n*=63) ICUs with six or more beds suitable for mechanical ventilation and officially recognised by the Netherlands Intensive Care Society. Paediatric ICUs were excluded.

Measurements and results: There was an 87% (*n*=55) response rate of contacted ICUs. The number of tracheostomies per year per unit varied widely (range 1-75), most ICUs (42%) performing between 11 and 25 tracheostomies per year. In 44% of ICUs (*n*=24) tracheostomy was not performed on a routine basis. In 25% of ICUs (*n*=14), tracheostomies were performed during the second week of ventilation. Surgical tracheostomy and percutaneous procedures were technique of first choice in 38% and 62% of ICUs respectively. In only 7% of units late follow-up protocols were in use. Thirty-two units (58%) reported a total of 56 major complications.

Conclusions: Timing and technique of tracheostomy varied widely in Dutch ICUs. The percutaneous technique is the procedure of choice for tracheostomy in most of these units. Late follow-up protocols are rarely in use.

Introduction

Until the beginning of the twentieth century, tracheostomy was an emergency procedure, the main indication being upper airway obstruction with asphyxia. After the poliomyelitis epidemic in Copenhagen, tracheostomy was performed not only to support ventilation, but also for pulmonary toilet[1]. The operative technique used was always surgical tracheostomy.

Since the widespread introduction of percutaneous tracheostomy in 1985, its use has increased steadily[2]. Three percutaneous techniques are widely used; progressive dilational tracheostomy (Ciaglia), conic dilational tracheostomy (Blue Rhino) and guide wire dilating forceps tracheostomy (Griggs)[2-4].

We suspected that major differences might exist in the timing and technique of tracheostomy between ICUs. Therefore, we performed a survey with the aim to investigate the use and technique of tracheostomy for long-term ventilated patients in Dutch ICUs.

Materials and Methods

In August 2001, an anonymous questionnaire was sent to the medical directors of all ICUs officially recognised by the Netherlands Intensive Care Society with six or more beds suitable for mechanical ventilation. Paediatric ICUs were excluded. Data were collected covering the year 2000 (Supplement 1).

Definitions

In the Netherlands, intensivists are usually internists, anaesthesiologists or surgeons with a special training in intensive care medicine. The majority of Dutch ICUs is mixed, containing medical, surgical and/or neurosurgical patients in one unit. 'Long-term ventilation' was defined as mechanical ventilation for more than five days. 'Major complications' were defined as a bleed requiring surgical intervention, oesophageal perforation, pneumothorax, tracheal stenosis and/or death related to the procedure.

Statistical analysis

Analysis was performed on anonymous data with Statistical Product and Service Solutions (SPSS) version 10.0. Categorical and continuous variables were compared, using cross tabs with Chi-square testing and Students T-test, where appropriate. Statistical significance was set at $p<0.05$.

Results

Response and ICU-characteristics (questions 1 to 4).

A total of 63 ICUs in the Netherlands fulfilled the inclusion criteria. The response rate was 87% (n=55). Because of the anonymity of this survey, analysis of non-responders was not possible. Of the 55 ICUs, 32 units had 6-10 beds, 14 units had 11-20 beds, six units had 21-30 beds and three units had 31-40 beds available for mechanical ventilation. Admissions per year and the percentage of patients requiring long-term ventilation are shown in Table 1. Most ICUs (49%) admitted 500-1000 patients per year. In three ICUs (6%), the percentage of long-term ventilated patients was less than 5%, whereas in ten ICUs (18%) this was more than 25%. We estimated that approximately 59.000 patients were admitted over the year 2000.
The medical director was an intensivist in 87%, while 13% had no director, but a multidisciplinary medical staff.

Frequency, timing and operator (questions 5 to 9).

Taking all responding ICUs together, approximately 1500 tracheostomies were performed per year. The number of tracheostomies per year per unit varied widely (range 1-75), with the majority of units (42%) performing between 11 and 25 procedures per year. The percentage of long-term ventilated patients receiving a tracheostomy is shown in Table 2.

Table 1. Admissions per year and the percentage of patients requiring long-term ventilation.

Admissions/ year	<500	500-1000	1001-2000	2001-3000	3001-4000	
Long-term ventilated patients						Total long-term ventilated patients
< 5%	-	1(1.8%)	1(1.8%)	1(1.8%)	-	3(5.5%)
5 – 10%	1(1.8%)	6(10.9%)	2(3.6%)	1(1.8%)	1(1.8%)	11(20%)
11 – 15%	-	7(12.9%)	5(9.1%)	-	-	12(21.8%)
16 – 20%	2(3.6%)	2(3.6%)	2(3.6%)	-	1(1.8%)	7(12.7%)
21 – 25%	2(3.6%)	2(3.6%)	1(1.8%)	2(3.6%)	-	7(12.7%)
> 25%	3(5.5%)	6(10.9%)	1(1.8%)	-	-	10(18.2%)
Not reported	1(1.8%)	3(5.5%)	1(1.8%)	-	-	5(9.1%)
Total admissions/year	9(16.4%)	27(49.1%)	13(23.6%)	4(7.2%)	2(3.6%)	55(100%)

Table 2. Percentage of long-term ventilated patients receiving a tracheostomy.

Long-term ventilated patients receiving a tracheostomy	0%	1 -10%	11 – 20%	> 20%	not reported	
Long-term ventilated patients						Total long-term ventilated patients
< 5%	-	1(1.8%)	1(1.8%)	1(1.8%)	-	3(5.5%)
5 – 10%	-	5(9.1%)	4(7.2%)	1(1.8%)	1(1.8%)	11(20%)
11 – 15%	-	6(10.9%)	5(9.1%)	1(1.8%)	-	12(21.8%)
16 – 20%	-	2(3.6%)	3(5.5%)	2(3.6%)	-	7(12.7%)
21 – 25%	-	-	1(1.8%)	3(5.5%)	1(1.8%)	5(9.1%)
> 25%	-	7(12.7%)	2(3.6%)	3(5.5%)	-	12(21.8%)
not reported	-	4(7.2%)	-	-	1(1.8%)	5(9.1%)
Total long-term ventilated patients receiving a tracheostomy	-	25(45.5%)	16(29.1%)	11(20.0%)	3(5.5%)	55(100%)

In 25 ICUs (46%), 1-10% of long-term ventilated patients received a tracheostomy, in 16 ICUs (29%) this was 11-20% and in 11 ICUs (20%) this was more than 20%. Three ICUs (6%) were unable to provide reliable data. The timing of tracheostomy in long-term ventilated patients was highly variable (Figure 1). Overall, intensivists performed the procedure in 31%, surgeons in 31% and otorhinolaryngologists in 13% of cases. In 26% of the ICUs a multidisciplinary team performed the tracheostomy (Table 3). In 25% of ICUs (*n*=14) written guidelines regarding the indications for and the practice of tracheostomy were available.

Figure 1. Timing of routinely performed tracheostomy stratified by operator.

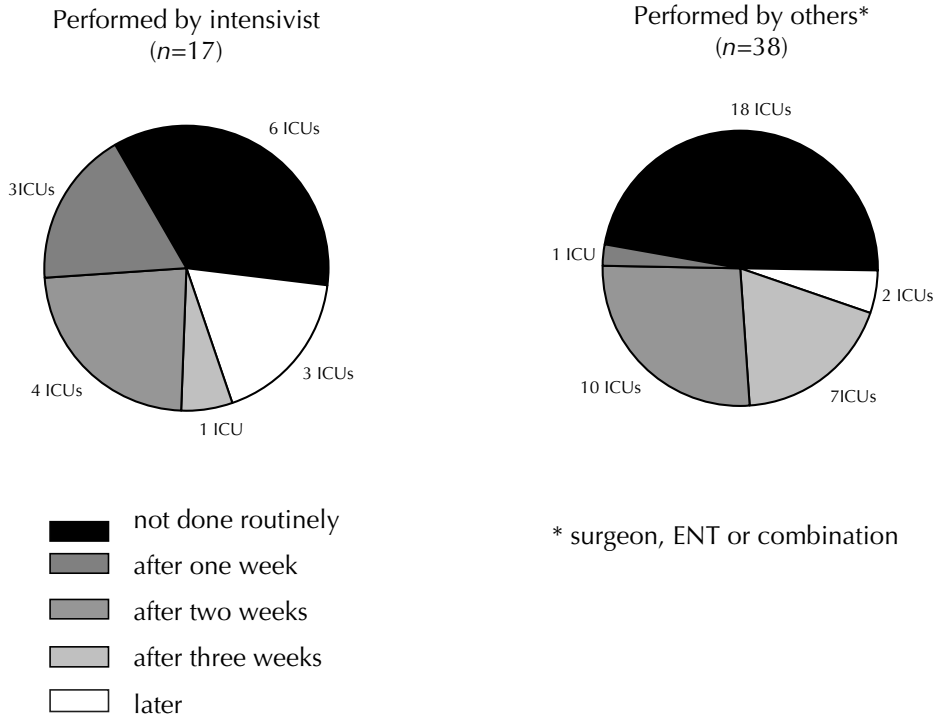


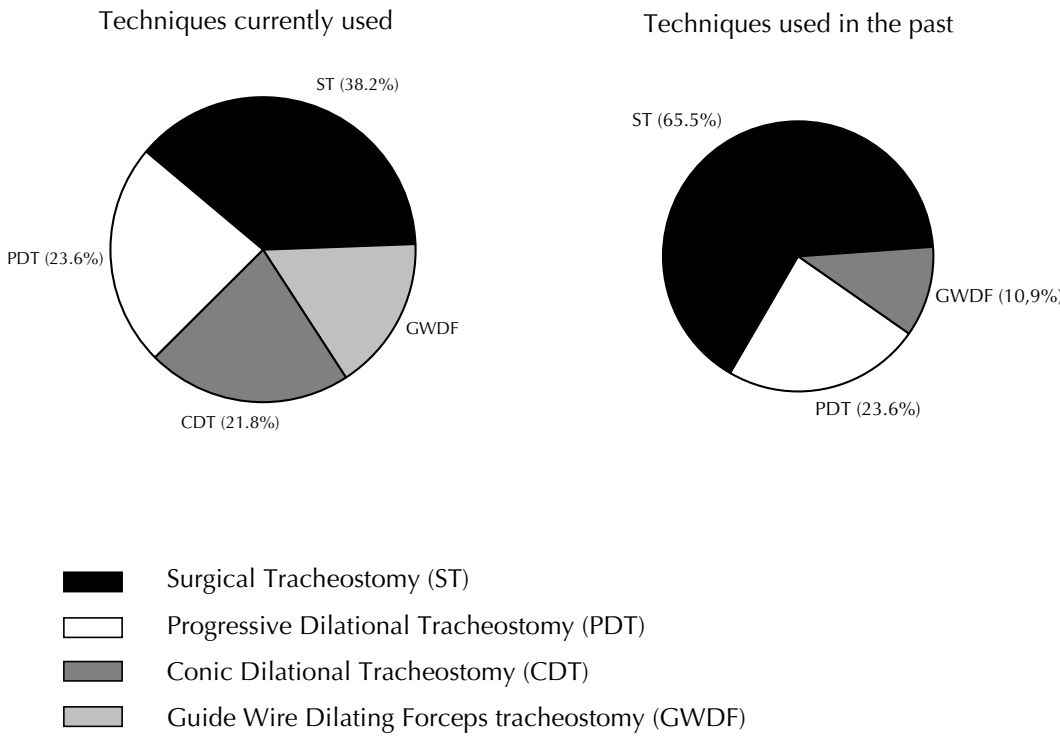
Table 3. Physician performing the procedure.

	Surgical tracheostomy	Percutaneous tracheostomy	Total physician
Intensivist	0	17	17
Surgeon	8	9	17
ENT-surgeon	7	0	7
Combination	6	8	14
Total tracheostomies	21	34	55

Choice of technique (questions 10 to 14).

The distribution of the different techniques in use is shown in Figure 2.

Figure 2. Techniques of tracheostomy.



Of units using percutaneous tracheostomy, fibre-optic control was used in 36% (*n*=12). To obtain an idea of the change in preferred technique over time, we also asked which technique was used more then one year ago. This showed a clear trent towards the increasing use of percutaneous tracheostomy.

Location where tracheostomy is performed (question 15).

Of 21 units using surgical tracheostomy, 16 units (76%) performed the procedure in the operating theatre, one unit (5%) in the ICU and the remaining four units (19%) on both locations. Of the 34 units using percutaneous tracheostomy, 32 units (94%) performed the procedure in the ICU. Percutaneous tracheostomy was significantly more often performed in the ICU than surgical tracheostomy ($p<0.01$).

Follow-up and major complications of tracheostomy (questions 16 to 20).

Only seven percent of participating ICUs (*n*=4) had formal long-term follow-up protocols. Twenty-three units reported no major complications of tracheostomy. The other ICUs (*n*=32) reported major complications in a total of 56 patients. Of these, 16 underwent surgical and 40 underwent percutaneous tracheostomy (Figure 3).

Opinion of intensivists (question 21).

Of units using surgical tracheostomy, only 44% (*n*=8) considered this to be the method of choice and 33% (*n*=6) considered it safer than percutaneous tracheostomy. In contrast, almost all units (94%) using percutaneous tracheostomy considered this to be the method of choice and 50% (*n*=17) thought that it was safer than surgical tracheostomy. These differences were statistically significant ($p<0.01$) (Figure 4).

Figure 3. Number of patients with a major complication per ICU.

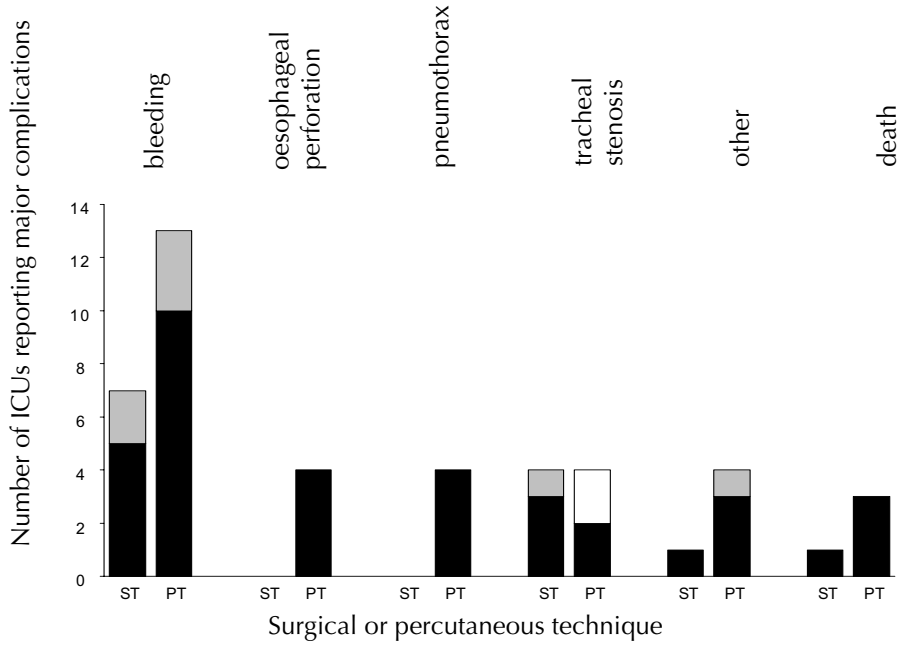
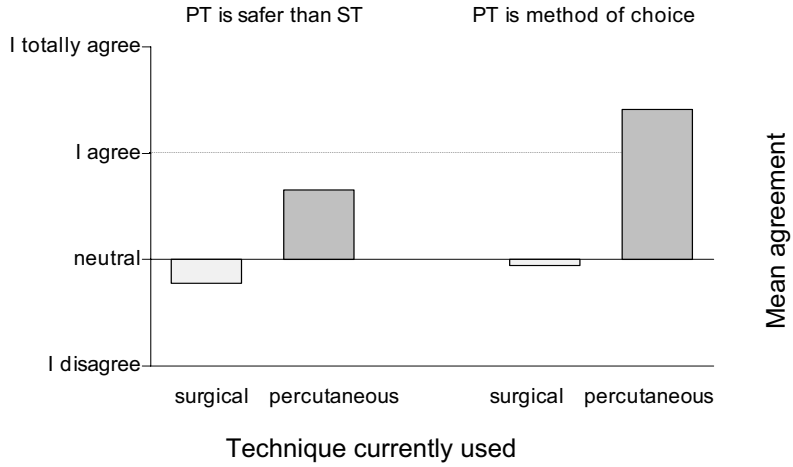


Figure 4. Opinions of the responding ICUs stratified to technique currently used.



Discussion

This survey shows that clinical practice concerning the timing and performance of tracheostomy in long-term ventilated patients varies widely among intensive care units (ICUs) in the Netherlands. Although tracheostomy is considered a relatively safe alternative to tracheal intubation, it is neither done routinely nor uniformly. As expected, there is a large variation in timing of tracheostomy in our survey. Almost half of the responding ICUs never performed a tracheostomy routinely, while in the remaining units the timing varied considerably. Sound guidelines on timing of tracheostomy are difficult and a recent review concluded that there is insufficient evidence to support the hypothesis that the timing changes the duration of mechanical ventilation or extent of airway injury in patients on the ICU[5]. We were unable to show that "self-sufficient" units (intensivist as performer of the procedure) performed more tracheostomies, or did the procedure earlier on, compared to "otorhinolaryngology/ surgery-dependant" units.

The benefits and risks of tracheostomy are well known in the ICU. Numerous studies have tried to compare surgical and percutaneous tracheostomy, with contradictory results[6-8]. Both techniques are likely to coexist until robust evidence becomes available about the superiority of one or other technique[9]. However, most physicians in our survey believe that the percutaneous technique is the procedure of choice for critically ill patients who require tracheostomy, although this opinion is heavily influenced by the technique currently in use, as could be expected. Understandably, with the increasing popularity of percutaneous tracheostomy, the acceptance of this technique will also increase. Indeed, there was an increase in the total percentage of percutaneous tracheostomies, from 35% more than one year ago to 62% at the time of the survey. This is comparable to the prevalence in Switzerland and Germany (57% and 51.3% respectively), but it is still less than in the UK (78%)[10-12]. Almost all percutaneous tracheostomies in our survey took place in the ICU, whereas the majority of surgical tracheostomies took place in the operating theatre.

When the percutaneous technique is used, there was an almost equal representation of progressive dilational tracheostomy, conic dilational tracheostomy and guide wire dilating forceps tracheostomy. Only 36% of the ICUs used fibre-optic control during

the procedure. This is comparable to the survey from the UK (31%), but far less than reported in a recent survey from Ireland (88%)[12,13].

Thirty-two ICUs reported a total of 56 major complications, mainly peri-operatively and during cannulation. Of major late complications, tracheal stenosis is often asymptomatic and is only diagnosed after a careful endotracheal examination[14]. Therefore, its incidence will often be underreported. The number of reported complications is comparable to the survey from Ireland, stressing the fact that percutaneous tracheostomy is an invasive procedure not without complications[13]. Although the number of severe complications appears to be higher in the percutaneous group, the retrospective collection of these data makes a useful comparison impossible. These data only give an impression of the nature of major complications occurring when tracheostomies are done. However, because of its general applicability and ease of use, the number of complications with the percutaneous technique may increase, when performed outside rigorously controlled clinical trials.

In conclusion, the timing and technique of tracheostomy in Dutch intensive care units varied widely. Written guidelines are only present in a minority of hospitals. Although the percutaneous technique is considered to be the procedure of choice and safer than the surgical technique, further controlled studies are necessary to determine the optimal timing and the specific procedure according to different patient groups.

Acknowledgements

The authors thank Dr. E.N. Robertson and Dr. O.H.G. Wilder-Smith for the review of the text and language editing. The study received no external financial support.

Supplement 1

Questionnaire "Tracheostomy on the ICU"

I General questions

1) How many adult ICU-beds do you have for mechanical ventilation?

If possible, give the exact number over the year 2000: …….

- ❑ ≤ 5
- ❑ 6 - 10
- ❑ 11 - 20
- ❑ 21 – 30
- ❑ 31 – 40
- ❑ > 40

2) How many adult ICU admissions do you have per year (on average)?

If possible, give the exact number over the year 2000: …….

- ❑ < 500
- ❑ 500 - 1000
- ❑ 1001 - 2000
- ❑ 2001 - 3000
- ❑ 3001 – 4000
- ❑ > 4000

3) What percentage of patients is ventilated for five or more days (= long-term ventilation)?

- ❑ < 5 %
- ❑ 5 - 10 %
- ❑ 11 - 15 %
- ❑ 16 - 20 %
- ❑ 21 - 25 %
- ❑ > 25 %

4) Who is medical director of the ICU or who has full medical responsibility?

- ❑ Intensivist
- ❑ Anaesthesiologist
- ❑ Surgeon
- ❑ Internist
- ❑ Mixed

II Specific questions regarding tracheostomy

5) If long-term ventilation (five or more days) is necessary, do you routinely perform a tracheostomy? If yes, when?

- ❑ No
- ❑ Yes, after one week
- ❑ Yes, after two weeks
- ❑ Yes, after three weeks
- ❑ Yes, later

6) What is the absolute number of tracheostomies per year?
If possible, give the exact number over the year 2000: ……

- ❑ 0
- ❑ 1 - 10
- ❑ 11 - 25
- ❑ 26 - 50
- ❑ 50 – 75
- ❑ > 75

7) What percentage of long-term ventilated patients (five or more days) receives a tracheostomy?

- ❑ 0 %
- ❑ 1 - 10 %
- ❑ 11 - 20 %
- ❑ > 20 %

8) Do you have guidelines on how to perform a tracheostomy?

- ❑ Yes
- ❑ No

9) Who performs the tracheostomy?

- ❑ Intensivist
- ❑ Surgeon
- ❑ Otorhinolaryngologist
- ❑ Combination
- ❑ Other: ……

10) Which technique is in favour? (more than one answer possible)

- ❑ Surgical tracheostomy
- ❑ Percutaneous tracheostomy, Ciaglia (multiple dilators)
- ❑ Percutaneous tracheostomy, Blue Rhino (single dilator)
- ❑ Percutaneous tracheostomy, Griggs (dilating forceps)
- ❑ Minitracheostomy
- ❑ Other: ……

11) If both surgical and percutaneous techniques are in use, how do they compare to each other (in numbers)?

- ❑ Surgical : Percutaneous = ….. : …..

12) Which technique did you use in the past (longer than one year ago)?

- ❑ Surgical tracheostomy
- ❑ Percutaneous tracheostomy, Ciaglia
- ❑ Percutaneous tracheostomy, Griggs
- ❑ Minitracheostomy
- ❑ Other: ……

13) How many minitracheostomies do you use per year?

- ❑ 0
- ❑ 1 - 10
- ❑ 11 – 25
- ❑ 26 - 50
- ❑ > 50

14) When a percutaneous tracheostomy is performed, is bronchoscopy routinely used?

- ❑ Yes
- ❑ No

15) Where is the tracheostomy performed?

- ❑ In the ICU
- ❑ In the operating theatre
- ❑ In the ICU and operating theatre about equally

16) Do you use long-term follow-up protocols?

- ❑ Yes
- ❑ No

17) Which type of cannula do you use generally?

- ❑ Shiley
- ❑ Portex
- ❑ Tracoe
- ❑ Other: ……..

18) Do you use fenestrated cannulas (to facilitate speech) and if yes, when?

- ❑ No
- ❑ From the beginning
- ❑ After 0 - 1 weeks
- ❑ After 1 - 2 weeks
- ❑ Later

19) Can patients with a tracheostomy be cared for on the nursing ward?

- ❑ No
- ❑ Yes, but only on General Surgery
- ❑ Yes, but only on Otorhinolaryngology
- ❑ Yes, but only Neurology
- ❑ Yes, but only on General Surgery, Otorhinolaryngology and Neurology
- ❑ Yes, but only (different combination): ……
- ❑ Yes, everywhere

20) Have you experienced any major complications in the last year?

If so, can you indicate what number?

- ❑ None
- ❑ Bleed requiring surgical intervention. (… x)
- ❑ Oesophageal perforation (… x)
- ❑ Pneumothorax (… x)
- ❑ Tracheal stenosis (… x)
- ❑ Other …… (… x)
- ❑ Died (… x)

21) Can you give your opinion on the following statements?

	Totally agree	*Agree*	*Neutral*	*Disagree*	*Totally disagree*
a. Percutaneous tracheostomy is safer than surgical tracheostomy:					
b. Percutaneous tracheostomy is the method of first choice:					
c. On my ICU, there are indications for the use of a minitracheostomy:					

22) Do you object when I contact you?

- ❑ Yes
- ❑ No. You can reach me at :

Name :

Institute :

Phone number :

23) General remarks:

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Chapter 4 a

Primary laryngospasm in a patient with Parkinson's disease: treatment with CPAP via minitracheotomy following intubation

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Durk F. Zandstra

Intensive Care Medicine 1995; 21: 863-864

We would like to report on a primary laryngospasm in a patient with Parkinson's disease and it's treatment with CPAP (continuous positive airway pressure) via minitracheotomy.

A 60-year old man with about a 10-year history of Parkinson's disease treated with Sinemet (carbidopa and levodopa) was admitted to the hospital with a life-threatening upper airway obstruction. He was intubated, and mechanical ventilation was initiated. Chest X-ray revealed bilateral basal consolidations. After three days, the condition has improved, blood gases were normal and the patient could be extubated. Stridor immediately resumed, however. On fiberoptic bronchoscopy, the vocal cords appeared to be almost completely adducted without edema or sings of inflammation.

A minitracheotomy was performed with a cannula 4 and treatment with continuous-flow CPAP connected to the cannula was started. This resulted in a marked reduction of the stridor, with adequate ventilation. The patient was successfully weaned from this CPAP arrangement without recurrent laryngospasms and was transferred to the ward after five days with cannula in situ. Additional investigation with body-plethysmography breathing showed a marked increase in inspiratory resistance, with almost normal expiratory resistance, pattern in accordance with extrathoracic, variable airflow obstruction, e.g. vocal cord dysfunction. Episodes of severe stridor recurred after two weeks. On direct laryngoscopy, the vocal cords were still adducted. A permanent tracheostomy was performed tot avoid further ICU admission and interventions.

In Parkinson's disease, dopamine depletion leads to diminished inhibition of the extra pyramidal motor system. This may lead to severe laryngospasm. Respiratory problems are well known, and aspiration pneumonia is one of the most common causes of death among such patients[1].

Dysfunction of the upper airways has only recently been recognized in patients with Parkinson's disease[2]. In most cases, this leads to impairment of static and dynamic pulmonary function. In some patients, laryngeal involvement was the main reason for airway obstruction[2]. In our patient, the most likely diagnosis is primary laryngospasm associated with Parkinson's disease.

Treatment by minitracheotomy connected to a continuous flow CPAP resulted in a clinically relevant relief of stridor.

The mechanism of this effect might be the slight positive airway pressure of 2–4 cm H_2O in combination with a 4 mm free artificial airway. However, the latter cannot be the only explanation for the clinical relief of stridor, since the stridor increased while the patient was breathing through an open minitracheostomy without CPAP connection. Although minitracheotomy is most frequently used in the treatment of sputum retention, it allows an artificial airway to be combined with several other arrangements[3,4].

In conclusion, laryngospasm caused by dysfunction of recurrent laryngeal nerves may be associated with Parkinson's disease. CPAP via minitracheotomy proved to be temporarily successful in the management of this problem. Tracheostomy may be inevitable in case of persistent relapses.

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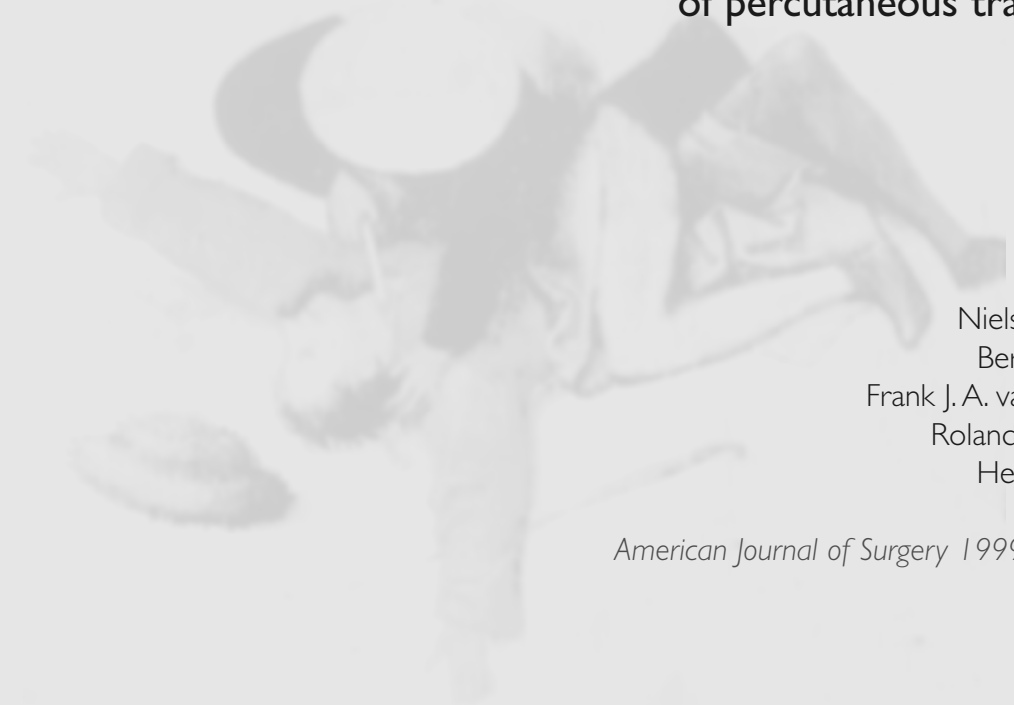
Chapter 4 b 1

The guide wire dilating forceps technique of percutaneous tracheostomy



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American Journal of Surgery 1999; 177: 311-315

Abstract

Background: Prospective evaluation of the percutaneous tracheostomy by the guide wire dilating forceps (GWDF) technique.

Methods: In 50 selected patients percutaneous tracheostomy with fiberscopic control was performed and evaluated.

Results: Most percutaneous tracheostomies were performed without any adverse effect. No life-threatening complications or deaths were related to the procedure. The procedure was successful in 49 of 50 patients (98%). In one patient the procedure was converted to an open tracheostomy because a significant bleeding occurred. Five peri-operative complications, including this significant bleeding and four minor complications, occurred in 50 patients (10%). Early complications occurred in 6 of 48 patients (13%), including one significant bleeding and 5 minor complications. A subglottic stenosis occurred in 2 of 36 successfully decannulated patients (6%). In one case this was certainly due to prolonged endotracheal intubation.

Conclusions: The GWDF technique is a safe and efficient bedside alternative for open tracheostomy. Fiberscopic control is recommended to increase the safety of the procedure. Although studies of late complications are necessary, it appears to be justifiable to consider percutaneous tracheostomy in patients who require tracheostomy.

Introduction

In 1626 Sanctorio Sanctorius was probably the first surgeon to describe a percutaneous tracheostomy[1]. However, it was not until 1955 that the term percutaneous tracheostomy was introduced by Shelden et al.[2]. They described a method to insert a cannula percutaneously. Fourteen years later Toye and Weinstein[3] used a Seldinger wire as a guide for introducing a cannula. In 1985 Ciaglia et al.[4] were the first to describe percutaneous tracheostomy using sequentially larger dilators for gaining access to the trachea, the so-called Progressive Dilational Tracheostomy (PDT). Later Schachner et al.[5] and Griggs et al.[6] each described an alternative technique; the Rapitrac technique and the guide wire dilating forceps (GWDF) technique respectively. Both methods are based on a specially developed instrument that is used for rapid dilation. Unlike the dilating forceps by Griggs, the Rapitrac by Schachner has a sharp, cutting edge to easily penetrate the pretracheal tissues as it is advanced over the guide wire. The dilating forceps are a modification of the "Howard Kelly" forceps that have curved jaws to avoid possible damage to the lateral and posterior wall of the trachea.

Many patients, who are in need of prolonged mechanical ventilation or assisted bronchopulmonary toilet, undergo tracheostomy. With the development of percutaneous tracheostomy a simple alternative for standard surgical tracheostomy (hereafter called "open tracheostomy") became available.

Percutaneous tracheostomy seems to offer advantages over open tracheostomy. It is a quick bedside procedure and many studies have already shown the safety of percutaneous tracheostomy[6-21]. The aim of this study was to evaluate the GWDF technique and the early and late results. The first 50 patients on whom percutaneous tracheostomy was performed using this technique were evaluated.

Patients and methods

This prospective study is based on the data of 50 consecutive patients who underwent percutaneous tracheostomy in the period March 1997 till April 1998 in the University Hospital St. Radboud Nijmegen, the Netherlands.

All patients requiring tracheostomy were judged on their ability to undergo percutaneous tracheostomy. Contraindications for performing percutaneous tracheostomy were: young age (<16 years), emergency situation, and severe distortion of the anatomy in the neck region. The patients and/or relatives of the patients gave informed consent prior to the procedure. All patients who underwent percutaneous tracheostomy were registered using a standard form. Reason of hospitalisation, duration of endotracheal intubation prior to tracheostomy, indication for tracheostomy, complications and duration of the procedure were recorded. Peri-operative complications were defined as complications related to the procedure and occurring during or immediately after the procedure (within six hours). Early complications were defined as complications occurring in the period between six hours and fourteen days after the procedure. Late complications were defined as complications occurring from two weeks onwards after the procedure.

In June 1998 twenty-three of the 36 successfully decannulated patients were interviewed with regard to late complications. Special attention was paid to dyspnea, stridor, voice changes, hoarseness, problems swallowing and cosmetic deformity. All data were analysed and compared with the literature of percutaneous tracheostomy. In order to compare data from this study with data from other studies, we tried to match definitions and complications.

Technique

The percutaneous tracheostomies were carried out as a bedside procedure in the intensive care unit by the investigators or under their direct supervision at the bedside on the intensive care unit except for two patients. General anesthesia was given according to protocol (propofol, rocuronium and fentanyl). All patients were ventilated with pressure controlled ventilation using 100% oxygen before the procedure was started and were monitored with continuous pulse oximetry, electrocardiography, and end-tidal carbon dioxide measurements.

For the GWDF technique a Portex Percutaneous Tracheostomy Kit is available (SIMS Portex Limited, Hythe, Kent, UK). This kit contains a scalpel, a cannulated needle with syringe, a guide wire, an initial tracheal dilator, dilating forceps and a tracheostomy tube mounted on an obturator. The procedure was performed as described elsewhere[6].

Results

In 50 selected patients (25 men and 25 women) whose median age was 62 years (range 17-82) percutaneous tracheostomy was performed electively. Almost half of the patients suffered from some sort of neurological problem.

In 88% of all cases the indication for tracheostomy was prolonged ventilatory dependence or difficult weaning. The median duration of endotracheal intubation prior to tracheostomy was 14 days (range 0-49). Only one patient had not been intubated endotracheally until a percutaneous tracheostomy was performed for reason of broncho-pulmonary toilet.

The majority of the percutaneous tracheostomies was performed without any adverse effect. All but two were performed in the intensive care unit. These two patients underwent percutaneous tracheostomy in the operating room. Percutaneous tracheostomy was combined with another procedure in one patient. In the second patient the practicability of percutaneous tracheostomy was doubted, because of uncertainty in identifying the anatomical landmarks. To prevent problems in case of a possible conversion to open tracheostomy, percutaneous tracheostomy was performed in the operating room. The procedure was performed rapidly and uneventfully.

The mean procedure time was 8.9 minutes (range 2-33 minutes, median 7 minutes) from skin incision to completion of the tracheostomy. The procedure was successful in 49 of 50 patients (98%). One patient developed a significant venous bleeding after dilation of the trachea. Percutaneous tracheostomy was therefore converted to open tracheostomy.

The tracheostomy tube was first changed after median 12 days (range 2-57 days). In most cases the Portex tracheostomy tube was replaced by a (usually fenestrated) Shiley nr. 6 tracheostomy tube due to preference of the nursing staff to the latter system. One patient received a Shiley nr. 4 tube, because the stoma was too small for a Shiley nr. 6 tube. One patient no longer required mechanical ventilation at the time the tube was changed. This patient received a minitracheotomy tube for broncho-pulmonary toilet. A silver cannula was placed in one patient. This patient was known to have a subglottic stenosis, for which he had received a tracheostomy from 1986 till 1991. It was expected that the tracheostomy tube had to stay in place for a long period. Decannulation was succesfully performed after 83 days.

Forty-eight patients were followed postoperatively. One patient was transferred to Germany one day after tracheostomy and one patient underwent open tracheostomy. Both patients were lost to follow-up. Eleven of the 48 patients (23%) died before decannulation and 6 patients (13%) died after decannulation. None of these deaths was related to either tracheostomy or decannulation.
The median duration of stay in the intensive care unit after percutaneous tracheostomy was performed was 17.5 days (range 1-155), whereas the median duration of total stay in the intensive care unit was 33 days (range 5-162). The median duration of cannulation in successfully decannulated patients (*n*=36) was 26.5 days (range 6-106).

Peri-operative complications
Five peri-operative complications occurred in 50 patients (10%) as shown in table 1. Once the cannula was inserted pretracheally due to kinking of the guide wire. This was followed by a minor bleeding. The pretracheal insertion was immediately discovered and corrected. The bleeding was controlled by local pressure. This patient developed mild subcutaneous emphysema that resolved spontaneously.
In one patient a superficial lesion of the posterior tracheal wall occurred, causing minor bleeding, which was discovered immediately thanks to fiberscopic control of the procedure. The bleeding stopped spontaneously after tracheal suction.
Significant venous bleeding occurred in one patient who had anticoagulation therapy after cardiothoracic surgery. The tracheostomy tube could not be inserted and the procedure was converted to open tracheostomy. At exploration the insertion of the needle appeared to be between the cricoid and first tracheal ring.

Early complications
Early complications occurred in 6 of 48 patients (13%). Minor bleeding occurred in three patients and all were managed by local pressure. Two patients had excessive purulent exudate from the tracheal wound. No cellulitis occurred. Specific therapy was not necessary. In one patient who had a coagulation abnormality significant bleeding occurred. Reexploration was needed two days after percutaneous tracheostomy. Diffusely bleeding thyroid tissue was managed by electrocoagulation. The patient required no transfusion. This complication had no adverse affects for the patient. The

open tracheostomy was followed by a minor bleeding. This bleeding was managed by local pressure.

Late complications

Most of the late complications develop after decannulation. Of the 50 patients who underwent percutaneous tracheostomy, 36 were successfully decannulated. In June 1998 these 36 patients were reviewed for late complications of percutaneous tracheostomy. Twenty-three of these 36 patients were also interviewed with regard to late complications. At the moment of reviewing late complications 6 of the 36 patients were no longer alive, 6 had severe neurological damage and one patient could not be traced. These 13 patients were reviewed for late complications only by reviewing their charts and interviewing their family doctors The median follow-up was 7 months with a minimum of 2 months.

Six of the 36 patients developed a late complication. Table 1 hows all late complications and is divided as major late complications and minor late complications. In two patients (6%) a major late complication occurred. In both cases it concerned a subglottic stenosis. One patient was seen 3 months after decannulation because of progressive stridor. This patient had been intubated endotracheally for 20 days prior to tracheostomy and had been cannulated for 11 days. Using flexible laryngoscopy a left sided vocal cord paralysis and a subglottic swelling was found. Initially systemic therapy with corticosteroids sufficed, but 3 months later operative intervention was necessary. At direct laryngoscopy a severe stenosis was seen two centimetres subglottic with a lumen of only a few millimetres. An endotracheal Dumont stent was placed after dilation. To date this stent is in place for three and a half months. In one patient direct laryngoscopy was performed by an experienced Ear, Nose, and Throat surgeon, because decannulation had failed due to progressive stridor. A bridge of scar tissue was seen between the left and right tracheal wall with a small residual lumen both ventral and dorsal of this bridge of scar tissue. Distal to the stenosis the tracheostomy tube could just be seen. These deformities were the result of prolonged endotracheal intubation and not of tracheostomy. This patient had been intubated endotracheally for 26 days prior to percutaneous tracheostomy. Later this patient died due to septic shock.

No tracheocutaneous or tracheo-esophageal fistula occurred due the procedure.

Table 1. Complications in this study.

Complications	*n*	%
Peri-operative complications (50 patients)		
Minor bleeding[1]	1	2
Significant bleeding[2]	1	2
Major bleeding[3]	0	0
Subcutaneous emphysema	1	2
Pretracheal insertion	1	2
Superficial lesion of the posterior tracheal wall	1	2
Total	5	10
Early complications (48 patients)		
Minor bleeding[1]	3	6
Significant bleeding[2]	1	2
Major bleeding[3]	0	0
Excessive purulent exudate at the stoma	2	4
Total	6	13
Major late complications (36 patients)		
Subglottic stenosis (see text)	2	6
Total	2	6
Minor late complications (36 patients)		
Minor bleeding[1]	1	3
abnormal granulation tissue	1	3
hoarseness / voice changes (23 patients)	2	9[#]
Total	4	15

[1] defined as bleeding controlled by local measures, not requiring re-exploration or transfusion

[2] defined as bleeding requiring re-exploration, no transfusion, not life-threatening

[3] defined as life-threatening bleeding, requiring transfusion and emergency surgery

[#] as a percentage of 23 interviewed patients

In 4 of the 36 patients a minor late complication occurred. In one patient, who had been cannulated for 39 days, a minor bleeding occurred during decannulation. Replacement of the cannula and inflating of the cuff sufficed to stop the bleeding. This

patient was decannulated without any problems eight days later, but died eventually due to a septic shock.

Hoarseness and voice changes were registered only in patients without history of pre-existing vocal problems. One of the 23 interviewed patients had the feeling that his voice had changed. Direct laryngoscopy revealed no deformities. Slight hoarseness was registered in one patient who underwent cardiothoracic surgery prior to percutaneous tracheostomy. This patient refused to undergo laryngoscopy. Asymptomatic patients were not subjected to laryngoscopy.

In one patient abnormal granulation tissue of the skin was treated. In all patients the tracheostomy scar was smaller than 1.5 cm and cosmetically acceptable.

In the mean time the tracheostomy has healed without sequelae in 32 of 36 patients. One patient is alive with the cannula still in situ and probably will never be decannulated because of his severe pulmonary condition.

Discussion

There is no universal agreement about the "safe" duration of endotracheal intubation. Endotracheal intubation and tracheostomy both have clear advantages and disadvantages. In this study the median duration of endotracheal intubation prior to tracheostomy was 12 days. However, the wide range (0-49 days) indicates their is no consensus on the timing of tracheostomy, although there is an increase of complications of endotracheal intubation with an increasing duration of intubation[22]. Tracheostomy facilitates nursing, communication and patient comfort[23]. In this and other studies percutaneous tracheostomy is attended with low complication rates. It appears to be justifiable to consider percutaneous tracheostomy at an early stage in patients who are endotracheally intubated. However, we cannot provide a simple formula to determine the timing of tracheostomy.

The GWDF technique is one of the techniques of percutaneous tracheostomy. The descriptions of this technique in the literature are limited[6,7] in contrast with the Progressive Dilational Tracheostomy[8-10,12-21]. As is seen in Table 2, both techniques have low complication rates.

Table 2. Peri-operative and immediate postoperative complications in the literature.

Authors	*n*	Complications	(%)	*n*	Complications	(%)
GWDF technique	*Peri-operative*			*Postoperative*		
Griggs et al. (1990)[6]	75	1	(1)	Not reported		
Griggs et al. (1991)[7]	153	2	(1)	153	4	(3)
this study	50	5	(10)	48	6	(13)
cumulative	278	8	(3)	201	10	(5)
PDT technique	*Peri-operative*					
Ciaglia et al. (1992)[9]	165	14	(8)			
Winkler et al. (1994)[10]	71	4	(6)			
Petros et al. (1997)[12]	137	15	(11)			
Hazard et al. (1988)[13]	55	6	(11)			
Marelli et al. (1990)[14]	61	4	(7)			
Friedman et al. (1993)[15]	100	18	(18)			
Gaukroger et al. (1994)[16]	50	5	(10)			
Toursarkissian et al. (1994)[17]	141	16	(11)			
van Heurn et al. (1996)[18]	100	16	(16)			
Berrouschot et al. (1996)[19]	76	6	(8)			
Fernandez et al. (1996)[20]	162	9	(6)			
Cobean et al. (1996)[21]	65	14	(22)			
cumulative	1183	127	(11)			
Rapitrac technique	*Peri-operative*					
Schachner et al. (1989)[5]	80	14	(18)			
Cole et al. (1994)[22]	55	28	(58)			
cumulative	135	42	(31)			

On the other hand the "Rapitrac" technique is attended with higher complication rates[5,22]. In Table 2 only studies with 50 or more patients were considered.

Complication rates after open tracheostomy vary widely. Stock et al.[23] describe complication rates ranging from 6-51%. However, both studies on percutaneous tracheostomy and open tracheostomy use different definitions, methods and duration of follow-up, and therefore are difficult to compare. For this reason we tried to match definitions and complications in order to compare data from this study with data from other studies.

Few studies compare percutaneous tracheostomy and open tracheostomy prospectively. Griggs et al.[7] concluded that percutaneous tracheostomy is attended with fewer complications than open tracheostomy (3.9% vs. 18.9%). Hazard et al.[8] described a significant difference of 6 complications following 24 percutaneous tracheostomies (25%) versus 14 complications following 24 open tracheostomies (58%). Stoeckli et al.[11] compared prospectively 47 patients, who underwent PDT, and 36 patients, who underwent open tracheostomy. They found significantly fewer complications with performing PDT than with performing open tracheostomy (6.4% vs. 36.1%).

Most studies advocate percutaneous tracheostomy as a safe and efficient alternative to open tracheostomy, that can be performed at the bedside in the intensive care unit. This is confirmed by the low peri-operative and early postoperative complication rates in this study. Only twice a complication (significant bleeding) occurred that made surgical intervention necessary. Other complications resolved spontaneously or with simple measures. No life-threatening complications occurred.

The procedure lasted, on average, 8.9 minutes (range 2-33). In several studies the duration of percutaneous tracheostomy without fiberscopic control varies from 4.3 to 13.6 minutes[8,13,19]. Fiberscopic control in this study seems to have no adverse effect on average procedure time. The duration of uncomplicated percutaneous tracheostomy can be prolonged by fiberscopic control, but the same fiberscopic control might shorten procedure time of complicated procedures. The advantages of using fiberscopic control are evident[10]. Berrouschot et al.[19] compared percutaneous tracheostomy with and without fiberscopic control. The peri-operative complication rates were equivalent (7% vs. 6%), but in the group without fiberscopic control more severe complications

occurred (two cases of perforating the rear tracheal wall, one death due to tension pneumothorax). They concluded that fiberscopic control minimizes the severity of complications. Two important steps of the procedure (puncture of the trachea and insertion of the guide wire) are confirmed by using fiberscopic control. Besides that, important complications (laceration of the tracheal wall and pretracheal or intraesophageal insertion) can be prevented in most cases, or at least be immediately discovered and treated. Fiberscopic control offers the advantages of learning the procedure at the same time.

Little is known about late complications of percutaneous tracheostomy. Their is no agreement on how tracheal damage should be assessed, although most authors use radiological examination[8,13,24]. Asymptomatic patients may have a minor stenosis. However, such a "benign" stenosis seems of no practical importance. Late complications may have been missed due to the limited follow-up period. In most cases symptoms suggesting tracheal damage develop within two months after decannulation, but symptoms may also appear many months, even years, after decannulation[25]. Hoarseness and voice changes are described after percutaneous tracheostomy[15]. However, it seems more likely that hoarseness and voice changes are caused by endotracheal intubation, because the tracheostomy tube is localized a few centimetres beneath the vocal cords. It is also difficult to determine whether the registered late complications are related to the technique of tracheostomy or to other factors (duration of endotracheal intubation, duration of cannulation, cannula size), because the same type of complications occurs due to open tracheostomy. Prospective studies comparing late complications of percutaneous tracheostomy and open tracheostomy are necessary to draw conclusions regarding late complications.

In conclusion, the GWDF technique is a safe and efficient bedside alternative for open tracheostomy and can replace open tracheostomy in many cases. The GWDF technique is easy-to-learn and is attended with low complication rates, that are comparable with complication rates after PDT. Fiberscopic control of intratracheal localisation of needle and guide wire is recommended to increase the safety of the procedure. Although studies of late complications are necessary, it appears to be justifiable to consider percutaneous tracheostomy in patients who require tracheostomy for airway control or broncho-pulmonary toilet.

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Chapter 4 b II

Percutaneous tracheostomy with the guide wire dilating forceps-technique: presentation of 171 consecutive patients

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Head and Neck 2002; 24: 625-631

Summary

Background: Evaluation of percutaneous tracheostomy (PT) with the guide wire dilating forceps (GWDF) technique.

Design: Prospective study of peri-operative complications, retrospective analysis of early and late complications.

Setting: ICU in a teaching university hospital.

Results: The success rate of the procedure was 96.5%. The average procedure-time in 171 consecutive patients was 5.0 minutes. Peri-operative complications requiring surgical or medical intervention occurred in 6.4% of 171 patients. This included conversion to surgical tracheostomy, which was necessary in six patients (3.5%). Major complications while cannulated occurred in 2.4% of 164 patients but seemed mostly unrelated with the GWDF technique itself. Late complications (after decannulation) were mostly minor and occurred in 22.6% of 106 patients. Only one patient (0.9%) developed a symptomatic tracheal stenosis.

Conclusion: Percutaneous tracheostomy with the guide wire dilating forceps technique is easy to perform at the bedside with few late complications. However, in our study, peri-operative and immediate postoperative bleeding complications (minor and major) occur quite often.

Introduction

Percutaneous tracheostomy (PT) has gained widespread acceptance to control the airway in patients requiring prolonged ventilatory support in the intensive care unit. Several techniques are available, although until recently only two are widely used viz., the Progressive Dilational Tracheostomy (PDT) technique and the guide wire dilating forceps (GWDF) technique[1]. Since the introduction of the PDT in 1985, the frequency of this procedure has increased steadily[2]. The PDT technique has been investigated in several studies and is regarded as a safe alternative to surgical tracheostomy[3-5]. However, the repetitive passage of consecutive wider dilators can be time-consuming and can lead to hypoxaemia and hypercarbia as well as injury to the posterior tracheal wall[6,7]. In 1990 Griggs developed the GWDF technique that appeared to be easier to perform and within less time than the PDT technique[8]. This technique uses dilating forceps for a two-step dilation of the tracheal wall. We have described the results with our first 50 patients earlier and found that the incidence of serious adverse events was low (around 5%)[9]. The aim of this study was to further evaluate this procedure.

Materials and methods

All patients requiring tracheostomy between March 1997 and February 2000 at the University Medical Center Nijmegen were judged on their ability to undergo PT. The main indication for tracheostomy was an endotracheal intubation with an expected duration of ventilation of more than two weeks. In patients with difficult oxygenation (PEEP higher than 20 cm H_2O, FiO_2 higher than 70%), a large goiter, past surgery in the neck, emergency surgery, age younger than 16 years and a total body weight of less than 40 kg, PT was contraindicated. The regional center of home ventilation prefers a surgical semi-permanent tracheostomy with a so-called Björk flap, so patients who were thought to be candidates for home ventilation were also excluded for PT[10]. Relative contraindications were coagulation abnormalities and obesity with inability to identify the proper landmarks. The patients and/or relatives of the patients gave informed consent for study participation in accordance with the requirements of the local medical ethical review board prior to the procedure. The procedures were carried out as a bedside procedure in the intensive care unit according to a standard protocol

and were performed by a (fellow)-intensivist and a senior resident in surgery or otorhinolaryngology. An anesthesiologist was responsible for airway control and anesthesia (propofol, rocuronium and fentanyl). All patients were ventilated with pressure controlled ventilation with a FiO_2 of 1.0. During the procedure, monitoring was done with at least pulse oxymetry, electrocardiography and capnography.

The GWDF technique was done with a Portex Percutaneous Tracheostomy Kit (SIMS Portex Limited, Hythe, Kent, United Kingdom) (Figure 1 and 2). The patient's head was positioned in retroflexion with a transverse pillow under the shoulder blades. The tube was withdrawn under direct vision with a laryngoscope so that the inflated cuff was in-between the vocal cords. The trachea was punctured with a cannulated needle (Figure 3). The guide wire was inserted through this cannula (Figure 4). The position and depth of the tracheal puncture as well as the position of the guide wire were routinely checked with a fiberscope in all patients. Subsequently, the forceps are used to dilate the tracheal wall (Figure 5). The technique is described in more detail elsewhere[8].

Patient demographics were registered using a standard form at the time of the procedure. Reason of hospitalization, duration of endotracheal intubation prior to tracheostomy, indication for tracheostomy, peri- and postoperative complications and duration of the procedure were recorded. Duration of the procedure was defined as the time interval between skin incision to successful placement of the cannula. The procedure was judged as difficult when the skin incision had to be enlarged and/or when the dilation procedure had to be repeated more then twice. Complications were classified as follows. Peri-operative complications were defined as complications related to the procedure and occurring during or within 24 hours after the procedure. Complications while cannulated were defined as complications occurring in the period between 24 hours and until removal of the cannula. Late complications were defined as complications occurring after removal of the cannula. Major complications were defined as complications requiring surgical or medical intervention, like life-threatening bleeding or esophageal perforation requiring a surgical exploration or infection with the need for antibiotic therapy. Long-term follow-up information was provided by retrospective review of medical records and phone interviews with the patients. When they were unable to communicate their close relatives were interviewed. Registered patient information of the standard forms was entered in a specifically constructed database. Descriptive statistics of the study group were computed using the statistical program SPSS (version 10.0).

Results

A total of 171 patients, including the first 50 patients that were described before[9], underwent elective percutaneous tracheostomy (PT). The median age was 62 years (range 15–84) with 99 men (58%) and 72 women (42%). Underlying reason for ICU admission of the patients who underwent PT are referred to in Table 1. The majority (39%) suffered from some sort of neurological problem. In 84% of all cases the indication for tracheostomy was prolonged ventilatory dependence. The median duration of endotracheal intubation from admission to the ICU to tracheostomy was 17 days (range 1-92). In all patients fiberscopic guidance was used. The majority of the percutaneous tracheostomies were performed without any adverse effects and the procedure was successful in 165 of 171 procedures (96.5 %). The median procedure time was 5.0 minutes (mean 9.1 minutes, SD 8.3 minutes). The median duration of cannulation was 24 days (range 2-679).

Table 1. Underlying reason for ICU admission (all patients *n*=171).

Underlying illness	Frequency	(%)
Neurological disease	66	(38.6)
Respiratory disease	28	(16.4)
After cardiac surgery	18	(10.5)
After abdominal surgery	13	(7.6)
Cardiorespiratory arrest	8	(4.7)
Septic shock	7	(4.1)
Not classified	31	(18.1)
Total	171	(100)

Peri-operative complications

In six patients (3.5%) the cannula-insertion was judged as difficult. Postoperative emphysema occurred in two patients (1.2 %). It subsided completely after a few days without any specific treatment. Major peri-operative complications occurred in 11 out of 171 patients (6.4%) as shown in Table 2. In six patients (3.5 %) major bleeding occurred. In four, this could be corrected with diathermy and/or sutures, but in two the

procedure was converted to surgical tracheostomy: one developed a major venous bleeding after dilation of the trachea and the tracheostomy tube could not be inserted. In the other patient arterial blood was aspirated initially and the procedure was abandoned. A life threatening bleeding occurred in one patient. At the end of the procedure, he suffered severe breathing-problems with a fall in arterial saturation. After direct removal of the cannula, large clots were suctioned from the trachea with improvement of oxygenation. Eventually, the patient could be discharged without residual problems. No deaths were related to the procedure.

Table 2. Peri-operative complications (all patients *n*=171).

Peri-operative complications	Frequency	(%)	
No complications	128	(74.9)	
Minor complications:			
Hypotension	1	(0.6)	
Puncture of endotracheal tube	9	(5.3)	
Puncture of posterior tracheal wall	4	(2.3)	
Bleeding (local pressure)	11	(6.4)	
Emphysema	2	(1.2)	
Cannula insertion difficult	6	(3.5)	
Accidental detubation	1	(0.6)	
Total minor peri-operative complications	34	(19.9)	
Major complications:			Conversion to surgical tracheostomy
Bleeding (surgical exploration)	6	(3.5)	2
Bleeding (life-threatening)	1	(0.6)	
Cannula insertion impossible	3	(1.8)	3
Esophageal perforation	1	(0.6)	1
Total major peri-operative complications	11	(6.4)	

In four other patients the PT failed. Twice there were problems localizing the trachea with subsequent ventilatory problems (hypoxemia and hypercarbia). In one patient the guide wire was positioned correctly, but the cannula was inserted through the tracheal rearwall in the esophagus. Surgical exploration confirmed esophageal rupture and the tracheo-esophageal wall could be closed. Fortunately, the postoperative course was

uneventful. In one patient the distance from skin to tracheal lumen was too large to insert the cannula necessitating conversion to surgical tracheostomy.

Complications while cannulated.

Of 171 patients, six patients underwent surgical tracheostomy. Of 165 patients with a PT, one patient was lost to follow up so 164 patients could be analyzed for complications while cannulated as shown in Table 3.

Two patients had a stridor when the cannula was closed before attempting decannulation. In one patient this was due to scar tissue proximal to the cannula that was presumably caused by the endotracheal intubation. Finally, he died of septic shock before decannulation was possible. In the other patient, the stridor was due to edema which subsided spontaneously after several days so he could be decannulated uneventfully. Four patients had infectious complications. Specific therapy was not necessary. Two patients (1.2%) suffered a cardiorespiratory arrest, one shortly after decannulation and another patient after obstruction of the cannula with a mucous plug. A total of 54 patients (32.9%) died from their underlying disease with the cannula still in place or within one week after the cannula was removed after a median duration of cannulation of 22 days.

Table 3. Complications while cannulated (*n*=164).

Complications while cannulated	Frequency	(Percentage)
No complications	139	(84.8)
Minor complications		
Bleeding (local pressure)	15	(9.1)
Peristomal pain	1	(0.6)
Infection	4	(2.4)
Total minor complications while cannulated	20	(12.2)
Major complications		
Stridor	2	(1.2)
Cardiorespiratory arrest	2	(1.2)
Total major complications while cannulated	4	(2.4)

Late complications

Of 165 patients with a PT, 54 died with the cannula in place and five patients were lost to follow-up. In total, 106 patients could be successfully decannulated and analyzed for late complications as shown in Table 4. At the time of analysis (June 2001) 22 patients had died while decannulated, so their close relatives were interviewed. The median follow-up after discharge from the ICU was 2.5 years with a minimum of 14 months.

Table 4. Late complications (*n*=106).

Late complications	Frequency	(Percentage)
No complications	81	(76.4)
Cosmetic problems	10	(9.4)
Persistent hoarseness/voice changes (*)	9	(8.5)
Bleeding	2	(1.9)
Emphysema	1	(0.9)
Tracheal stenosis	1	(0.9)
Stridor	1	(0.9)
Total late complications	24	(22.6)

(*) without laryngeal abnormalities on indirect laryngoscopy

Nine patients (8.5%) complained of persistent hoarseness and/or voice change. All were offered consultation by an ENT-specialist (FJAH), but only two found their complaints serious enough to justify referral. ENT examination did not show objective laryngeal abnormalities that could explain the subjective voice changes. Ten patients (9.4%) mentioned cosmetic problems regarding the tracheostomy scar. Four of them underwent scar revision, two patients found their scar acceptable and four patients desired referral to an ENT-specialist (FJAH). Of those, two had minor abnormalities but the other two patients were offered corrective surgery. In two patients an inspiratory stridor developed. In one patient this was caused by a subglottic stenosis and she was treated with an endotracheal stent. In the other patient the stridor became manifest directly after decannulation and was due to reactive granulation tissue. It resolved

spontaneously. Two patients had bleeding problems: one patient had a stomal bleeding occurring during decannulation and one patient had bloodloss from her stoma five weeks after decannulation while still in the hospital. This was caused by granulation tissue and treated conservatively. In two patients the cannula-change was difficult; one developed subcutaneous emphysema after pretracheal placement of a new cannula.

Discussion

Percutaneous tracheostomy (PT) is becoming increasingly popular as an alternative to surgical tracheostomy. Endotracheal intubation and tracheostomy both seem to have clear advantages and disadvantages[11,12]. There is an increase of complications of endotracheal intubation with an increasing duration of intubation. Tracheostomy facilitates nursing, communication and patient comfort[13]. It should be considered at an early stage in patients who are likely to be endotracheally intubated for any longer length of time. In principle the decision has to be individualized for the specific patient at hand[14]. For selected groups recommendations have been made viz. patients with infratentorial lesions requiring mechanical ventilation[15]. In this study the median duration of endotracheal intubation prior to tracheostomy was 17 days (range 1-92). The wide range was due to the fact that some patients were extubated and reintubated before the decision was made to do a PT. Moreover, some patients were initially too unstable to undergo a PT, even though the endotracheal tube was in place for several weeks. In the medical literature there is no general agreement about the safe duration of endotracheal intubation[16,17].

The duration of the procedure and particularly the time that the patient is not adequately ventilated is critically in patients with severe respiratory difficulties. Besides, the advantage of performing the procedure in the ICU is offset when the procedure lasts too long because of the more inconvenient position of the surgeon at the ICU-bed compared with the operation table. In this study the median procedure time was five minutes (range 3-60). The duration of uncomplicated percutaneous tracheostomy is prolonged by fiberscopic control, although the same fiberscopic control might shorten procedure time of difficult procedures. The advantages of using fiberscopic control are clear[18,19]. Two important steps of the procedure (puncture of the trachea and insertion of the guide wire) are confirmed by using fiberscopic control. Other major complications

(laceration of the tracheal wall and pretracheal or intraoesophageal insertion) can also be avoided in most cases, or at least be immediately discovered and treated.

Many studies advocate percutaneous tracheostomy as a safe and efficient alternative to open tracheostomy and as a more cost-effective procedure[20-22]. However, it remains unclear whether the percutaneous technique should be preferred above surgical tracheostomy, since two recent meta-analyses found contradictory results[23,24].

Recently, the GWDF technique has been compared with the Ciaglia percutaneous tracheostomy technique, the most widely used and longest established technique of percutaneous tracheostomy[25-27]. Two of these studies were in favor of the Ciaglia technique, although only peri-operative and early postoperative complications were recorded[25,26]. In one study no statistical differences in complication rates were found[27]. The surgical time required for the GWDF technique was significantly less than that for the Ciaglia technique. The peri-operative and early postoperative complication rates in this study confirm the efficacy of the GWDF procedure. In one patient an acute life threatening complication (significant intratracheal bleeding) occurred. No other life-threatening complications occurred, although bleeding complications both peri-operatively and postoperatively occurred quite often (33 events affecting 31 patients, see Table 2 and 3). Although some bleeding problems may be explained by coagulation abnormalities due to medication or medical condition (thrombocytopenia, uremia), another explication may be the relatively uncontrolled dilation manoeuvre that may also give rise to tears in the tracheal wall and the anterior jugular veins. Finally, one patient had a symptomatic tracheal stenosis. The incidence of infectious complications while cannulated was low (2.3%). Even though some authors recommend prophylactic antimicrobial therapy before the procedure, our results do not justify this policy[28]. The incidence of major complications is in accordance with a comparable study[29]. Concerning voice-problems, like persistent hoarseness and/or voice change, it is not sure weather this is always due to the PT; presumably this could also been caused by the endotracheal tube or underlying neurological disease.

In conclusion, after 171 PT's we find GWDF easy to perform at the bedside with few late complications. However, in our study, peri-operative and immediate postoperative bleeding complications (minor and major) occur quite often.

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Chapter 4 c

Percutaneous tracheostomy with the Blue Rhino™ technique: presentation of 100 consecutive patients

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Anaesthesia 2002; 57: 1094-1097

Summary

We assessed the peri-operative, early and late complications in 100 percutaneous tracheostomies performed with the Blue Rhino™ kit. The success rate was 98%. Peri-operative complications occurred in 30 patients. Six major complications occurred; these included bleeding which required surgical exploration (*n*=3), and pneumothoraces (*n*=2) and one false passage. Cannula insertion was made easier by blunt dissection of the cervical tissues anterior to the trachea. The median duration of the procedure was 8.5 min, which is significantly longer than other authors' results. Only one major complication occurred while the patient was cannulated (serious bleeding requiring exploration). Finally, in a single patient a tracheal stenosis occurred as a major late complication, which eventually was treated by a successful tracheal resection. Percutaneous tracheostomy with the Blue Rhino™ kit is safe with a low incidence of major complications.

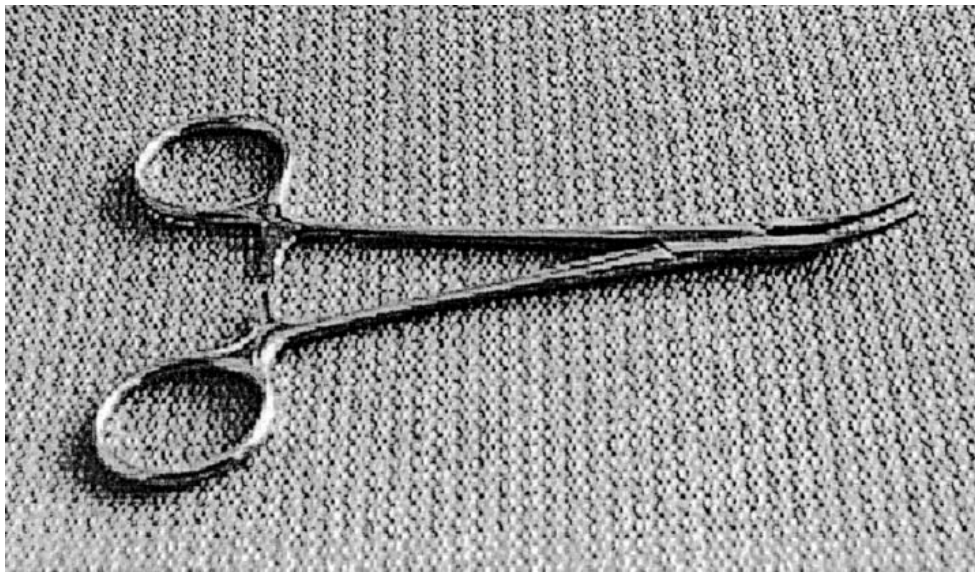
Introduction

Percutaneous tracheostomy is performed frequently to minimise complications associated with prolonged tracheal intubation in patients receiving ventilatory support in the intensive care unit (ICU)[1]. Many studies advocate percutaneous tracheostomy as a safe, efficient and cost-effective alternative to surgical tracheostomy[2-4]. Several techniques are available, although until recently only two have been widely used, both of which use Seldinger guidewire access to the trachea, the Ciaglia percutaneous tracheostomy technique and the guidewire dilating forceps technique[5,6]. Since the introduction of the multiple dilators Ciaglia percutaneous tracheostomy in 1985 and the guidewire dilating forceps technique in 1990, the popularity of the percutaneous techniques has increased steadily[7]. We have described the results with the guidewire dilating forceps technique in 171 patients and found major peri-operative complications in 6.4% of patients[8]. In 1999, the Blue Rhino™ was developed[9-12]; this new method seemed to combine the advantages of both previous techniques in that it is easy to perform, with fast controlled dilatation and any tracheostomy tube can be used. The aim of this study was to describe the early and late complications associated with percutaneous tracheostomy using the Blue Rhino™ kit.

Materials and methods

All patients requiring tracheostomy between March 2000 and August 2001 were considered for percutaneous tracheostomy. Indications and contraindications as well as the operative technique have been described in detail previously[9]. The patients consented or their relatives assented to study participation as required by the Local Research Ethics Committee. Percutaneous tracheostomy was carried out as a bedside procedure in the ICU according to a standard protocol. For the Blue Rhino™ technique, a Ciaglia Blue Rhino™ percutaneous tracheostomy kit was used (Cook, PO Box220, 5690 AE Son, The Netherlands). For both women and men, we used a size 8 Shiley low-pressure cuffed tracheostomy tube.

Figure 1. Crile's forceps



After local infiltration with lidocaine 1% with epinephrine 1:100,000, a 2.5 cm transverse incision was made through the skin and subcutaneous tissues. From patient 49 onwards, a curved Crile's forceps (Figure 1) was used for blunt dissection of the cervical fascia anterior to the trachea. Subsequently, the trachea was punctured with a 17G introducer needle below the cricoid cartilage, aiming for the interspace between first and second or second and third tracheal rings. After introducing the catheter into the trachea, the needle was withdrawn and the guidewire was threaded through the catheter. The position and depth of the tracheal puncture as well as position of the guidewire were always checked with a bronchoscope. A small dilator was used to predilate the puncture canal. The Blue Rhino™ dilator was mounted on a guiding catheter and advanced into the trachea until the 38 French mark on the Blue Rhino™ was seen with the bronchoscope. The dilator was left in place for 30 s; a Shiley tracheostomy tube was fitted over the 28 French loading dilator and advanced into position. The tracheostomy tube was connected to the ventilator and the correct position was confirmed by capnography.

Patient demographics were recorded at the time of the procedure using a standard form. Reason for hospital admission, duration of tracheal intubation prior to

tracheostomy, indication for tracheostomy, peri- and postoperative complications and duration of the procedure were recorded. Complications were classified[8] as 'peri-operative' if related to the procedure and occurring within 24 hours of the procedure. A 'difficult procedure' was defined when the dilatation procedure required unusual force and/or needed to be repeated more then twice. 'Complications while cannulated' were complications occurring after 24 hours until removal of the tracheostomy tube. 'Late complications' occurred after removal of the tracheostomy tube. 'Major complications' were complications requiring medical or surgical intervention, such as a bleed requiring suturing, oesophageal perforation requiring surgical exploration or infection requiring antibiotic therapy. 'Duration of the procedure' was the time between skin incision and successful placement of the tube. Long-term follow-up information was provided by retrospective review of medical records and telephone interviews with the patients themselves. When they were unable to communicate or when they had died, a close relative or family physician was interviewed.

Statistical analysis was performed using Statistical Product and Service Solutions (SPSS) version 10.0. For comparison of the first 48 procedures with the last 52 procedures, non-parametric tests were used and a $p<0.05$ was considered significant.

Results

A total of 100 patients underwent elective percutaneous tracheostomy. The mean age was 57 years (range 18-87 years); 70 patients were male. The mean duration of tracheal intubation from ICU admission to tracheostomy was 21 days (range 1-62 days). Some patients were extubated and re-intubated before the percutaneous tracheostomy was performed; others were initially too unstable to undergo a percutaneous tracheostomy despite the tracheal tube being in place for several weeks.

The mean procedure time was 12 min. 53 s. (range 2-60 min., median 8 min. 30 s.). The majority of the percutaneous tracheotomies were performed without any adverse effects and the procedure was successful in all but two patients. The mean duration of cannulation was 24 days (range 2-92 days, median 17 days). The mean stay on the ICU was 41 days (range 7-116 days).

In the first 48 tracheostomies, 15 procedures were judged difficult (31%). In almost all patients, tracheal dilatation required unusual force. From procedure 49 onwards, a curved Crile's forceps was used for blunt dissection of the cervical tissues anterior to the trachea. The rest of the percutaneous tracheostomy procedure was unchanged. In the last 52 percutaneous tracheostomies, the procedure was judged difficult in only four patients (8%), which differed significantly when compared to the first 48 (p=0.004). In total, 36 peri-operative complications occurred in 30 patients (Table 1).

Table 1. Peri-operative complications (n=100)

	n	
No complications	70	
Minor complications:		
Puncture posterior tracheal wall	2	
Accidental detubation	2	
Bleeding (controlled by local pressure)	14	
Puncture endotracheal tube	5	
Subcutaneous emphysema	1	
Hypotension	1	
Air leakage	2	
Difficult tube placement	3	
Total minor complications	30	
Major complications:		Conversion to surgical tracheostomy
Bleeding requiring exploration	3	
False passage	1	1
(Tension) pneumothorax	2	1
Total major complications	6	2

Six major peri-operative complications occurred in five patients. Three patients bled and required exploration. In one of these, bleeding was accompanied by a life-threatening tension pneumothorax. At surgical exploration, it appeared that the tracheostomy tube had been inserted through the cricothyroid membrane. The fourth patient developed a pneumothorax after a procedure that seemed uncomplicated, while, in the last, the percutaneous tracheostomy failed because of difficulty localising the trachea and subsequent false passage formation due to guidewire kinking. The percutaneous tracheostomy procedure was abandoned and the next day a surgical tracheostomy was fashioned.

Two patients underwent surgical tracheostomies. Ninety-eight patients were eventually analysed for complications while cannulated (Table 2). Eighty-two patients (83.7%) had no complications. In total, 16 complications occurred, most of which where minor (*n*=15). Bleeding when using the Crile's forceps was the same as before its use (eight in the first 48 patients compared to nine in the last 52). One patient bled two days postoperatively; on exploration; a venous bleed was stopped with two stitches. This was considered a major complication.

Table 2. Complications while cannulated (*n*=98)

	n	(%)
No complications	82	(83.7)
Minor complications		
Bleeding controlled by local pressure	7	(7.1)
Infection (cellulitis)	2	(2.0)
Infection (pus)	2	(2.0)
Air leakage	4	(4.1)
Total minor complications	15	(15.3)
Major complications:		
Bleeding requiring exploration	1	(1.0)
Total major complications	1	(1.0)

Of these 98 patients, 30 died with the tracheostomy tube in situ or within one week after decannulation; one patient moved abroad and was lost to follow-up and three still had a tracheostomy in place. The remaining 64 were successfully decannulated and analysed for late complications. At the time of analysis (February 2002), 14 patients had died while decannulated so a close relative and/or family physician was interviewed.

Fourteen, mostly minor, late complications (21.9%) were reported (Table 3). One patient (1.6%) suffered subglottic stenosis. This patient developed a serious upper airway obstruction after removal of the tracheostomy tube. During direct laryngoscopy, it appeared that the tracheostomy was placed unusually low and that the front wall of the trachea protruded into the tracheal lumen. A size 8 tracheal tube was used to dilate and stent the trachea. However, as the stenosis recurred, tracheal resection was necessary. Fortunately, the patient recovered uneventfully and had no residual complaints at one-year follow-up.

Table 3. Late complications (*n*=64)

	n	(%)
No complications	50	(78.1)
Minor complications		
Voice changes	7	(10.9)
Persistent hoarseness	5	(7.8)
Cosmetic problems	1	(1.6)
Total minor complications	13	(20.3)
Major complications		
Tracheal stenosis	1	(1.6)
Total major complications	1	(1.6)

Discussion

The aim of this study was to describe the early and late complications in the first 100 patients who had a tracheostomy using the recently been developed Blue Rhino™ technique. The procedure lasted, on average, 12 min. 53 s. This is significantly longer than reported in previous publications[9,10], where the mean operation time varied between 2 min. 7 s. and 2 min. 32 s. Although the majority of procedures were completed within 5 minutes, the procedure was sometimes prolonged because of problems puncturing the trachea, obtaining a good view with the bronchoscope and unfamiliarity with a new technique[13]. Initially, a time-consuming part of the procedure was the dilatation, which was judged difficult in 31% of our first 48 patients. However, using a Crile's forceps for blunt dissection of the cervical tissues made dilatation smoother and despite the additional manoeuvre, the total procedure time was shortened (from 13 min. 47 s. to 12 min. 2 s.). In contrast to the guidewire dilating forceps technique, any manufacturer's tracheostomy tube can be used with the Blue Rhino™ technique. In our hospital, Shiley tracheostomy tubes are preferred. Although this tracheostomy tube is convenient, its outer diameter is larger than other tubes, such as the Portex tracheostomy tube (12.2 mm vs. 11.9 mm)[14]. After one patient developed massive subcutaneous emphysema with a fenestrated tracheostomy tube, we have only used unfenestrated tubes.

Two life-threatening complications occurred. In one patient, the puncture site was too low and this resulted in tracheal stenosis. Clearly, this complication was unrelated to the Blue Rhino technique itself. The other patient had intratracheal bleeding which led to blood clots, acting as a ball-valve with subsequent pneumothorax development. Other complications were less important and resolved spontaneously or with simple remedial measures. Voice change and/or hoarseness occurred in 18.7% of patients. However, ENT examination failed to reveal glottic abnormalities that could be related to the percutaneous tracheostomy procedure, so we feel that this may be due to the orotracheal intubation.

In conclusion, percutaneous tracheostomy with the Blue Rhino™ seems safe and easy to perform at the bedside. We found a comparable complication rate with the guidewire dilating forceps technique[8]. In our experience, the procedure is made easier by blunt dissection before introduction of the Blue Rhino™ dilator.

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Chapter 4 d

Comparison of two percutaneous tracheostomy techniques, guide wire dilating forceps and Ciaglia Blue Rhino: a sequential cohort study

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Critical Care 2004; 8: R299-R305

Abstract

Introduction: To evaluate and compare the peri- and postoperative complications of the two most frequently used percutaneous tracheostomy techniques, namely guide wire dilating forceps (GWDF) and Ciaglia Blue Rhino (CBR).

Methods: A sequential cohort study with comparison of short-term and long-term peri-operative and postoperative complications was performed in the intensive care unit of the University Medical Centre in Nijmegen, The Netherlands. In the period 1997-2000 171 patients underwent a tracheostomy with the GWDF technique and, in the period 2000-2003, a further 171 patients according to the CBR technique. All complications were prospectively registered on a standard form.

Results: There was no significant difference in major complications, either peri-operative or postoperative. We found a significant difference in minor peri-operative complications ($p<0.01$), and minor late complications ($p<0.05$).

Conclusion: Despite a difference in minor complications between GWDF and CBR, both techniques seem equally reliable.

Introduction

Tracheostomy is usually performed in patients who need prolonged mechanical ventilation, frequent suctioning of bronchopulmonary toilet or have upper airway obstruction. The percutaneous tracheostomy is a minimally invasive, effective and reliable procedure and has become the alternative to surgical tracheostomy[1]. Almost all percutaneous procedures in the Netherlands are done according to one of the three following techniques: guide wire dilating forceps tracheostomy (GWDF), Ciaglia Blue Rhino (CBR) tracheostomy, and progressive dilation tracheostomy (classic Ciaglia)[2]. We have extensive experience with the first two techniques[3,4]. This study is a sequel to our previous reports. Several studies have compared different percutaneous techniques[5-12], but since CBR is a relatively new technique, a comparison with GWDF has been made only twice in two small prospective cohorts [5,12]. The strength of the present study is the large group of patients, so the incidence of relevant complications is more meaningful.

The aim of this study was to compare GWDF and CBR. The study not only focuses on the immediate peri-operative complications, but also describes the long-term sequelae of both techniques.

Materials and methods

This is a retrospective analysis of all patients who underwent percutaneous tracheostomy in the University Medical Centre Nijmegen between March 1997 and April 2003. We compared the two historic data sets that we have published before[3,4], but we specifically focused on the precise definition of early complications and long-term sequelae. Between March 1997 and February 2000, we performed percutaneous tracheostomy on 171 patients, using the GWDF technique. Between March 2000 and April 2003, we performed percutaneous tracheostomy on another 171 patients, using the CBR technique. Indications, contra-indications and technique for percutaneous tracheostomy are standardised[3,4]. Patients or family gave informed consent prior to the procedure. Ethical approval from the institution medical ethical committee was not obtained because the standard of care was provided and no other experimental treatments were introduced. Published data cannot be reduced to a single recognisable

patient. All data were recorded prospectively on pre-designed forms. 'Procedure time' was defined as the time from incision to successful placement of the cannula. A 'peri-operative complication' was defined as a complication related to the procedure and occurring during or within 24 hours of the procedure. Postoperative complications were divided into 'complications while cannulated' and 'late complications'. A 'complication while cannulated' was defined as a complication occurring in the period between 24 hours after the procedure until removal of the cannula. A 'late complication' was defined as a complication occurring after removal of the cannula up to a follow up of three years. Complications were divided into minor and major (Tables 2-4). Moreover, complications were classified as procedure-specific and procedure-non-specific. Hypotension was defined as a systolic blood pressure of less than 90 mm Hg. Hypoxaemia was defined as an arterial oxygen saturation of less than 90 percent. It was considered minor when lasting less than five minutes, and major when lasting longer. Information regarding late complications was obtained by structured interviews with patients who were decannulated successfully. Patients or close relatives were asked about voice changes, dyspnoea, stridor, pain, and cosmetic problems. Patients were also asked to grade specific problems as absent, minor or major. All data were analysed using Statistical Product and Service Solutions (SPSS) version 11.0. All variables were checked for normal distribution. Data were provided as mean +/- SD or median. Continuous variables were compared with Student's T-test or Mann-Whitney test as appropriate. Bonferroni's correction for multiple comparisons was used. Categorable variables were compared with the χ^2-test. A cut-off level <0.05 was accepted as statistically significant.

Results

Demographic data are shown in Table 1. The procedure was successful in 165 of 171 patients (96.5%) in the GWDF group and in 169 of 171 patients (98.8%) in the CBR group. The majority of tracheostomies were performed by an intensivist or fellow (under supervision). There was an increased number of procedures performed by a fellow in the CBR group compared to the GWDF group, 51 versus 27 ($p<0.01$).

Table 1: Demographic data. Values are in mean, (SD) and [median].

	GWDF	CBR	*p*-value
Age (years)	57.5 (18.2) [62]	57.5 (18.4) [62]	NS
Male/female	99/72	114/57	NS
Endotracheal intubation (days)	16.9 (12.2) [14]	20.3 (12.3) [18]	0.03
Procedure time (minutes)	9.1 (8.3) [5.0]	10.8 (10.5) [7.0]	NS
Cannulation time (days)	38.4 (63.4) [24]	29.6 (39.8) [18]	NS
Time in ICU (days)	39.4 (29.8) [33]	44.1 (38.3) [34]	NS

Peri-operative complications

Peri-operative complications are described in Table 2. In total, there were 47 peri-operative complications in 43 patients in the GWDF group, and 84 peri-operative complications in 71 patients in the CBR group ($p<0.05$). This difference is explained by a higher number of difficult dilations ($p<0.01$) and minor bleedings with the CBR technique. After the introduction of a Crile's forceps for blunt dissection of the pretracheal tissues preceding CBR, the procedure became much easier. In the GWDF group, 13 patients (7.6%) had a major complication compared to nine patients (5.3%) in the CBR group. All these major peri-operative complications were procedure-specific. One life-threatening bleeding in the GWDF group led to severe hypoxia at the end of the procedure. After removal of the cannula, large blood clots were suctioned from the trachea. There was no significant difference in the number of patients in whom conversion to a surgical tracheostomy was necessary. In the GWDF group, six patients underwent conversion to a surgical tracheostomy: one patient had a major venous bleeding after dilation of the trachea and the cannula could not be inserted. In another patient, arterial blood was aspirated and the procedure was terminated. In two patients, the trachea was difficult to locate, resulting in hypoxaemia and hypercapnia. In one patient the guide wire was placed correctly, but the cannula perforated the posterior tracheal wall and entered the oesophagus. Surgical exploration confirmed rupture of the oesophagus, and the tracheo-oesophageal wall was immediately repaired.

Table 2: Peri-operative complications. Values in numbers (percentages).

	GWDF* (*n*=171)		CBR* (*n*=171)		*p*-value
No complications	128	(74.9)	100	(58.5)	<0.01
Minor complications					
Procedure-specific:					
Bleeding (local pressure)	11	(6.4)	24	(14.0)	0.04
Difficult dilation	0		23	(13.5)	<0.01
Difficult procedure	6	(3.5)	7	(4.1)	NS
Subcutaneous emphysema	2	(1.2)	2	(1.2)	NS
Cannula insertion difficult	0		3	(1.8)	NS
Air leakage cuff	0		2	(1.2)	NS
Procedure-non-specific:					
Puncture endotracheal tube	9	(5.3)	8	(4.7)	NS
Puncture posterior tracheal wall	4	(2.3)	2	(1.2)	NS
Accidental detubation	1	(0.6)	3	(1.8)	NS
Hypotension	1	(0.6)	2	(1.2)	NS
Total minor complications	34	(19.9)	75	(43.9)	<0.01
Major complications					
Procedure-specific:					
Bleeding (exploration)	6	(3.5)	4	(2.3)	NS
Bleeding (life-threatening)	1	(0.6)	1	(0.6)	NS
Fausse route	2	(1.2)	1	(0.6)	NS
Oesophageal perforation	1	(0.6)	0		NS
Cannula insertion impossible	3	(1.8)	0		NS
Pneumothorax	0		3	(1.8)	NS
Total major complications	13	(7.6)	9	(5.3)	NS

Conversion to surgical tracheostomy	GWDF	CBR
	n=6	*n*=2
	2	
		1
	1	
	3	
		1

*Some patients had more than one complication

The post-operative course was uneventful. In the last patient the distance between skin and trachea was too large to insert a cannula. In the CBR group two patients underwent surgical tracheostomy: in one patient the trachea was difficult to locate, and the cannula was placed pretracheally due to guide wire kinking. Another patient developed a major bleeding and a tension pneumothorax several hours after the procedure. After immediate drainage with a chest tube, surgical exploration showed that the tracheostomy tube had perforated the cricothyroid membrane. No deaths were seen after neither procedure.

Complications while cannulated

In total, 164 GWDF and 169 CBR patients could be analysed for complications while cannulated (Table 3). Four major complications (2.4%) occurred in the GWDF group, and seven major complications (4.1%) in the CBR group. One patient in the GWDF group had an obstruction of the cannula by a mucus plug, leading to a cardiorespiratory arrest. Another patient sustained a cardiorespiratory arrest shortly after decannulation, possibly due to aspiration. Both patients were resuscitated successfully. Three patients in the CBR group had an obstruction of the cannula: one of them died on his first day on the ward, possibly due to an obstructive blood clot in the cannula. The second patient had a mucus plug causing severe hypoxaemia. He received a minitracheotomy through the old tracheostomy opening. The third patient with an obstructed cannula was found in bed on the ward, having a respiratory arrest. The inner cannula, which was obstructed by a blood clot, was removed. The patient recovered uneventfully.

Table 3. Complications while cannulated. Values in numbers (percentages).

	GWDF		CBR		*p*-value
Surgical tracheostomy	6		2		
Lost to follow up	1		0		
Available for analysis	164		169		
No complications	139	(84.8)	138	(81.7)	NS
Minor complications					
Bleeding (local pressure)	15	(9.1)	14	(8.3)	NS
Infection	4	(2.4)	6	(3.6)	NS
Granulation tissue around stoma	1	(0.6)	1	(0.6)	NS
Pain from stoma	1	(0.6)	0		NS
Tracheal oedema	0		1	(0.6)	NS
Subcutaneous emphysema	0		1	(0.6)	NS
Dyspnoea	0		1	(0.6)	NS
Total minor complications	21	(12.8)	24	(14.2)	NS
Major complications					
Bleeding (exploration)	0		2	(1.2)	NS
Bleeding (life-threatening)	0		0		NS
Stridor (with empty cuff)	2	(1.2)	0		NS
Cardiopulmonary resuscitation	1	(0.6)	0		NS
Cannula obstruction	1	(0.6)	3	(1.8)	NS
Hypoxaemia	0		2	(1.2)	NS
Total major complications	4	(2.4)	7	(4.1)	NS

Late complications

Of 164 patients in the GWDF group, 53 (32.3%) died with the cannula in place or within one week after decannulation, and five patients were lost to follow-up. One hundred and seven GWDF patients (62.6%) could be decannulated successfully and analysed for late complications (Table 4).

Table 4. Late complications. Values in numbers (percentages).

	GWDF		CBR		*p*-value
Surgical tracheostomy	6		2		
Lost to follow up	5		6		
Still cannulated	0		3		
Deceased	53		60		
Available for analysis	107		100		
No complications	86	(80.2)	73	(73.0)	NS
Minor complications					
Voice problems/persistent hoarseness	9	(8.5)	22	(22.0)	<0.01
Cosmetic problems	10	(9.4)	2	(2.0)	0.04
Pain	0		2	(2.0)	NS
Total minor complications	19	(17.9)	26	(26.0)	NS
Major complications					
Stridor	2	(1.9)	1	(1.0)	NS

Of 169 CBR patients, 60 (35.5%) died with cannula in place or within one week after decannulation, six patients were lost to follow-up, and three patients had the cannula still in situ. Finally, 100 CBR patients (58.5%) were analysed for late complications. There was no significant difference between both groups regarding total late complications. All patients with voice problems were given the opportunity to consult

an ENT specialist. None of these had an objective laryngeal abnormality explaining their voice problems. Patients with cosmetic problems relating to the tracheostomy scar were offered specialist consultation. Six GWDF patients underwent scar revision. Three patients developed a severe stridor post decannulation. In the GWDF group, an 83-year-old woman had tracheal stenosis and was treated with an endotracheal stent and an 80-year-old woman was treated with laser for a granuloma just above the tracheostomy opening. In the CBR group, an 18-year-old man suffered from severe tracheal stenosis. He had a tracheal stent placed initially, but because of recurrence of the stenosis, a tracheal resection was necessary. The patient recovered uneventfully.

Discussion

In this study, we have compared two different techniques of percutaneous tracheostomy, guide wire dilating forceps (GWDF) and Ciaglia Blue Rhino (CBR). Both techniques are frequently used in the Netherlands, and are replacing the surgical technique[2]. This study showed no significant differences in clinically relevant complications between the two techniques. This is in agreement with two other studies comparing these techniques[5,12]. Although the total number of complications in the two groups in the study of Ambesh et al. was not significantly different, the authors noticed an increased rate of minor peri-operative bleeding in the GDWF group[5]. This was balanced by an increase in the number of patients with one ore more tracheal ring fracture in the CBR group (30%). The increase in major peri-operative bleeding with the GDWF technique may be explained by the poorly controllable dilation with the forceps[9]. Although the study of Añón et al. did not find any significant differences, in three of 26 patients in the GWDF group, there was an inability to insert the cannula[12].

Several other studies comparing progressive dilation (classic Ciaglia) and CBR[6,8], and progressive dilation and GWDF[7,9-11] have been described in the literature. Van Heurn et al. concluded that progressive dilation and GWDF are both reliable, but that progressive dilation has fewer early complications than GWDF[7]. Nates et al. also preferred progressive dilation to the GWDF technique, because of fewer surgical complications, less peri-operative and postoperative bleeding, and easier use[9]. Añón et

al. found a comparable complication rate, but the procedural time of the GWDF method was significantly shorter[10]. Unfortunately, comparing these studies is difficult, as complications were not defined uniformly.

In our study, a major complication while cannulated was obstruction of the cannula which occurred in four patients. These figures correspond with the prevalence of cannula obstruction in the literature (0.3-3.5%)[13-15]. Strict adherence to nursing protocols and a low threshold for cleaning the inner cannula should be the standard of care in the ICU. An outreach team from the ICU should visit patients, discharged to the general ward with a cannula in place, on a daily basis.

There are only few data available concerning late complications of percutaneous tracheostomy. Unfortunately, many confounders may be present, such as the disease process itself, the duration of endotracheal intubation, and other treatments in the intensive care unit (such as sedation or physical therapy). Moreover, patients as well as caregivers often interpret late complications subjectively. The total number of late complications in our study was not significantly different between the two groups. Subjective voice changes and hoarseness were more frequent in the CBR group ($p<0.01$). An explanation might be the longer mean endotracheal intubation time, as this is possibly the most important cause of voice problems. With progressive dilation tracheostomy, the incidence of voice problems ranges between 0-21%[16-22]. More patients in the GWDF group complained of cosmetic problems. Only a few studies have mentioned cosmetic complaints, but differences of opinion between patient and caregiver are frequent[23]. In each group in our study, one patient developed a critical, symptomatic tracheal stenosis. More patients may have had an asymptomatic tracheal stenosis, but because no additional diagnostic tests such as CT or MRI scans were performed, the actual incidence is unknown. Several studies have incriminated the GWDF technique as a cause of tracheal stenosis, but no studies with the CBR have been described. The incidence varied from 0–63%[18,23-27]. Most of these tracheal stenoses were asymptomatic.

Several factors may decrease the strength of our conclusions. Firstly, the study used historical data sets with a sequential design and therefore a time bias is possible. As

experience with percutaneous tracheostomy increases, the number of complications will decrease, even if another technique is used, although in our study this might well have been balanced by the fact that over time more fellows did perform the procedure. Secondly, scoring of the peri-operative complications by different physicians may be variable because of different interpretations. Despite these shortcomings, we conclude from our study that, although the CBR technique has more minor peri-operative complications, the two techniques are comparable. More prospective, randomised studies are required to adequately compare these different tracheostomy techniques. We are presently conducting a prospective, randomised study in which we compare GWDF and CBR tracheostomies. We specifically look for the occurrence of precisely defined early and late complications. The occurrence of tracheal stenosis will be analysed using the Forced Oscillation Technique (FOT) and MRI.

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Chapter 4 e

Percutaneous tracheostomy with the PercuTwist™ technique: not so easy

Description of technique and presentation of six consectutive cases

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Adapted from: *Anaesthesia 2002; 57: 935-936*

Summary

We have evaluated 6 percutaneous tracheostomies performed with the PercuTwist™ kit. The success rate was 100%. The dilation with the specifically designed screw was considered difficult in all but one procedure. There was one major peri-operative complication, a venous bleeding requiring surgical exploration. The median length of the procedure was 8.0 min. Percutaneous tracheostomy with the PercuTwist™ kit seems safe but we feel that the screwing procedure is difficult.

Introduction

Several techniques for percutaneous tracheostomy are available, although until recently only three have been widely used, all of which use Seldinger guide wire access to the trachea. These are the Ciaglia percutaneous tracheostomy technique with multiple and with one (Blue Rhino™) dilator and the guide wire dilating forceps technique. Recently, a new technique, the PercuTwist™, was introduced[1]. We wish to report our experiences with this technique.

Materials and methods

All patients requiring tracheostomy in April and May 2002 were offered a percutaneous tracheostomy with the PercuTwist™ kit (Rüsch, The Netherlands). Indications and contraindications have been described in detail previously. Percutaneous tracheostomy was carried out as a bedside procedure in the intensive care unit according to a standard protocol. After local infiltration with lidocaine 1% with epinephrine 1:100,000, a 2.5 cm transverse incision was made through the skin and subcutaneous tissues. Subsequently, the trachea was punctured with a 17 G introducer needle below the level of the cricoid cartilage, aiming for the interspace between first and second or second and third tracheal rings. After introducing the catheter into the trachea, the

guide wire was threaded and the needle was withdrawn. The position and depth of the tracheal puncture as well as position of the guide wire were routinely checked with a bronchoscope in all patients. After lubricating the hydrophilically coated PercuTwist™ screw in water for several seconds, it was introduced over the guide wire and screwed into the trachea under constant bronchoscopic control. The screw was withdrawn and the appropriately sized tracheostomy tube was introduced in the trachea. For women and men, we used the cuffed tracheostomy tube size 8 and 9 respectively that is contained in the set. Finally, the tube was connected to the ventilator and its position was confirmed by capnography.

The dilating procedure was described as by Frova previously[1]. A scale was used from I (controlled rotating dilation without any difficulties) to II (some difficulties but possible) and III (impossible, shift to another percutaneous technique). Complications were classified as follows. 'Peri-operative complications' were defined as complications related to the procedure and occurring during or within 24 hours after the procedure. 'Complications while cannulated' were defined as complications occurring in the period between 24 hours after the procedure until removal of the tracheostomy tube. 'Major complications' were complications requiring medical or surgical intervention, such as life-threatening bleeding or oesophageal perforation requiring a surgical exploration or infection requiring antibiotic therapy. 'Duration of the procedure' was the time between skin incision and successful placement of the tube.

Results

A total of six patients underwent elective percutaneous tracheostomy. The mean age was 46 years (range 27-61 years) with five men and one woman. The mean procedure time was 8 min. 00 s. (range 5-13 min.). The procedure was successful in all patients.

Of the six tracheotomies, five dilation procedures were judged as II: in those patients, the dilation of the trachea required much force. In order to avoid twisting of the skin by the screw, it needed to be stretched by an assistant. Only one major peri-operative complication occurred. This patient required surgical exploration several hours after the procedure. No complications while cannulated occurred.

Discussion

The aim of this report was to describe our experience with the recently developed PercuTwist™ technique. The procedure lasted, on average, 8 minutes. The most difficult part of the procedure was the dilation procedure, which was judged difficult in 5 of our 6 patients. One major complication occurred, a venous bleeding requiring surgical exploration.

In our unit we have used the guide wire dilating forceps technique in the past. We found major peri-operative complications in 6.4% of 171 patients[2]. Since the Blue Rhino™ kit became available, it is our preferred technique for percutaneous tracheostomy. We found major peri-operative complications in 5.0% of patients[3]. The first publication of the PercuTwist™ introduced it as a new technique, being both very simple and safe. However, a recent case-report draws attention to a serious complication[4]. We found a comparable complication rate in comparison with the guide wire dilating forceps and the Blue Rhino™ technique. We feel that the difficult dilation procedure is an important drawback of the technique.

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Chapter 5 a

False passage during percutaneous tracheostomy using the guide wire dilating forceps

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International Journal of Surgical Investigations 2001; 3: 469-472

Abstract

All cases of false passage during percutaneous tracheostomy using the guide wire dilating forceps technique were evaluated. False passage occurred in four of 170 patients. These cases are presented. The role of fibrescopic monitoring, capnography and other safety devices in preventing and detecting false passage are discussed. Although fibrescopic monitoring and capnography will not prevent all cases of false passage, they will certainly reduce the number of cases and enable early detection. Therefore they should be added to the standard procedure of percutaneous tracheostomy. Other safety advises should also be taken into account when performing percutaneous tracheostomy.

Introduction

The last 20 years percutaneous tracheostomy has become increasingly popular. Several percutaneous tracheostomy techniques exist. One of them is the guide wire dilating forceps technique[1]. This technique uses specially developed forceps for rapid dilation. Percutaneous tracheostomy has been advocated as a safe and efficient bedside alternative for open tracheostomy[2-4]. Since the introduction of the guide wire dilating forceps technique in our hospital, percutaneous tracheostomy has been performed successfully on more than 170 patients under fibrescopic control. False passage, i.e. misplacement of the dilating forceps or the tracheostomy tube, occurred in four of these 170 patients. In this paper these four cases are reported. The role of fibrescopic control and capnography in preventing and detecting false passage are discussed and some general safety advises are given.

Case reports

Patient 1

A 74-year-old woman underwent percutaneous tracheostomy using the guide wire dilating forceps technique, because she remained ventilatory dependent. After withdrawal of the endotracheal tube to the level of the subglottis, the trachea was punctured in the midline with a cannulated needle. Intratracheal localisation of the needle was verified by aspiration of air and by flexible tracheoscopy through the endotracheal tube. Subsequently the guide wire was inserted. The intratracheal localisation was verified again. The dilating forceps were advanced along the guide wire and used to dilate the pretracheal tissues and the tracheal wall in two steps. At this point bleeding occurred. Tracheoscopy was repeated and the forceps were not seen intratracheally. Apparently the forceps had been inserted pretracheally. After the bleeding had been stopped by local pressure, the procedure was resumed and completed without further problems. Postoperatively the patient developed mild subcutaneous emphysema that resolved spontaneously.

Patient 2

Percutaneous tracheostomy was performed on a 73-year-old woman with severe obstructive pulmonary disease, because of prolonged ventilation. The trachea was punctured in the midline and the guide wire was inserted. Both steps were controlled fibrescopically. The dilating forceps were advanced along the guide wire and used to dilate the trachea in two steps. Subsequently the tracheostomy tube was advanced along the guide wire and the guide wire was removed. However, removal of the guide wire required great effort and an obvious kink in the guide wire was seen. Therefore a false passage was suspected. The tracheostomy tube was indeed not seen intratracheally during fibrescopic control. The tracheostomy tube was removed. A new guide wire was inserted through the opening in the trachea, that had already been created with the dilating forceps, and the procedure was completed without any further problems. No postoperative complications were encountered.

Patient 3

A 73 year-old woman required prolonged ventilation after cardio-pulmonary resuscitation. Therefore percutaneous tracheostomy was performed as described before. Intratracheal localisation of the needle and the guide wire were verified by flexible tracheoscopy through the endotracheal tube. After dilation with the forceps, the tracheostomy tube with the obturator was inserted. After removal of the obturator the tracheostomy tube was connected to the ventilator. However, capnography did not detect carbon dioxide, making intratracheal localisation of the tracheostomy tube unlikely. The tracheostomy tube was removed immediately and ventilation was restored through the endotracheal tube. Due to difficulties with the reinsertion of the guide wire and the tracheostomy tube, the procedure was converted to an open tracheostomy. During the procedure a laceration of the posterior tracheal wall was seen. Surgical exploration was performed in the operation room to evaluate and restore possible damage to the tracheo-oesophageal wall. Both oesophagoscopy and tracheoscopy revealed a 3 cm long tracheo-oesophageal rupture. After incision of an extra two tracheal rings to gain better access to the rupture, the rupture was closed. At the end of the procedure no leakage of saliva was seen. Finally a cuffed tracheostomy tube was placed.

Postoperatively the patient was fed through a nasogastric tube during seven days. No adverse effects occurred, especially no pneumothorax, mediastinitis or tracheo-oesophageal fistula. The patient died 26 days later due to cardiac failure with the tracheostomy tube in place. During autopsy special attention was paid to the tracheo-oesophageal rupture. The rupture had healed well and no tracheo-oesophageal fistula was found.

Patient 4

Since a 70-year-old man with respiratory insufficiency remained ventilatory dependent, a percutaneous tracheostomy was performed. Insertion of the needle and the guide wire were confirmed with fibrescopic control. The forceps were inserted along the guide wire and dilation of the trachea was performed in two steps. Since the insertion of the tracheostomy tube required more effort than usual, false passage was suspected. Paratracheal insertion of the tracheostomy tube was confirmed with capnography. After removal of the tracheostomy tube the procedure was repeated and completed without further problems. No postoperative complications occurred.

Discussion

False passage can occur during several steps of percutaneous tracheostomy. During puncturing of the trachea the cannulated needle may be placed paratracheally or even in the esophagus, causing misplacement of the guide wire, the forceps and the tracheostomy tube. This can be prevented by fiberscopic monitoring of the insertion of the needle and the guide wire. Even if the guide wire is placed correctly, false passage may still occur. During insertion of the dilating forceps or the tracheostomy tube the guide wire may kink. This will lead to pretracheal or paratracheal insertion of the forceps and/or the tracheostomy tube. This is the most probable explanation of the false passage in our patients. Correct insertion of the forceps and the tracheostomy tube can be monitored fibrescopically to prevent false passage. However, in our clinic we do not routinely monitor those steps of percutaneous tracheostomy with a fiberscope. The dilating forceps and the tracheostomy tube have to be inserted into the trachea with the

correct curve, as shown in figure 1. In patients 1, 2 and 4 the forceps or tracheostomy tube was probably inserted with too sharp a curve. In patient 3 the curve was probably to wide, thus causing a lesion of the tracheo-esophageal wall with the rather pointed tip of the obturator. Insertion of the forceps or tracheostomy tube with the correct curve and knowledge of the normal anatomy of the trachea and the surrounding tissues are important to prevent false passage. As shown in Figure 1, the trachea is not positioned horizontally in a supine patient, but obliquely toward the spinal column. This oblique position of the trachea has practical consequences for the insertion of the needle, forceps and tracheostomy tube.

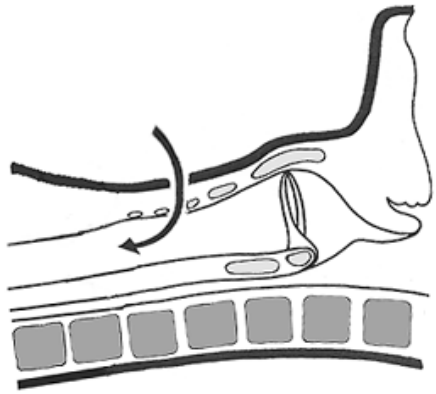

Figure 1. The forceps and the tracheostomy tube must be inserted with the right curve to prevent false passage. Note that the trachea is positioned obliquely toward the spinal column.

Although, several investigators recommend the use of fibrescopic control during percutaneous tracheostomy[3,5,6], fibrescopic monitoring of the insertion of the forceps and the tracheostomy tube is not always performed[4,7,8]. We suggest that fibrescopic monitoring of the whole procedure should be added to the standard procedure to prevent and quickly detect false passage. Correct placement of the tracheostomy tube can also be confirmed with capnography. If capnography does not measure carbon dioxide once the tracheostomy tube is connected to the ventilator, the tube is most likely placed incorrectly.

In conclusion, the following safety advises can be kept in mind to improve the safety of percutaneous tracheostomy:

1) Fibrescopic control through the endotracheal tube should be used to monitor insertion of the needle, the guide wire, the forceps and the tracheostomy tube.
2) The procedure should be performed by someone with good knowledge of the normal anatomy of the trachea and it's surrounding structures.
3) The dilating forceps and the tracheostomy tube should be inserted with the correct curve.
4) Capnography should be used to control placement of the tracheostomy tube.

Although these safety advises will not prevent all cases of false passage, they will certainly reduce the number of cases and enable early detection thus making the consequences of false passage less severe.

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Chapter 5 b

Emphysema and pneumothorax after percutaneous tracheostomy

case reports and an anatomic study

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Chest 2004; 125: 1805-1814

Abstract

Study objective:
Part 1: To describe cases of emphysema (subcutaneous and/or mediastinal) and pneumothorax after percutaneous tracheostomy (PT) in a series of 326 patients and to review the existing literature describing the incidence and possible mechanisms.
Part 2: To analyze the potential mechanisms for the development of emphysema and pneumothorax in human cadaver models.

Design: A retrospective analysis of PTs, in combination with an anatomic study in human cadavers.

Materials and methods:
Part 1: All ICU patients who underwent PT between 1997 and 2002 were enrolled in the study. We analyzed the cases of emphysema and pneumothorax. Similar cases were retrieved from the literature and subjected to a systematic review.
Part 2: The relevant anatomical structures were studied. We simulated the clinical situation after PT in a human pathological study in order to induce subcutaneous emphysema and pneumothorax.

Measurements and results:
Part 1: Five cases of subcutaneous emphysema (1.5%) and two cases of pneumothorax (0.6%) are described. In the literature search, we found 41 cases of emphysema (1.4%) and 25 cases of pneumothorax (0.8%) in a total of 3012 patients.
Part 2: Subcutaneous emphysema could easily be induced in a human cadaver model by inflating air in the pretracheal tissues and after posterior tracheal wall laceration. Air leakage was also possible through a fenestrated cannula via the space between the inner non-fenestrated cannula and outer cannula and then through the fenestration.

Conclusions: We conclude that one mechanism for the development of emphysema is an imperfect positioning of the fenestrated cannula whereby the fenestration is extraluminal. For this reason, fenestrated cannulas should not be used immediately after

placement of a PT. Posterior tracheal wall laceration is another mechanism responsible for emphysema after PT. After perforation of the posterior tracheal wall, the pleural space can be reached easily. This may result in a pneumothorax.

Introduction

For long-term ventilation, two techniques to control the airway are available: tracheostomy and endotracheal intubation. Percutaneous tracheostomy was first described in 1955[1]. In 1985, Ciaglia described the Progressive Dilational Tracheostomy (PDT)[2]. In 1990, an alternative technique was described by Griggs: the Guide Wire Dilating Forceps (GWDF) tracheostomy[3]. In 1998 Ciaglia developed the Conic Dilational Tracheostomy (CDT), better known as the Blue Rhino™ technique. It combined the advantages of PT and GWDF, i.e. fast and smooth concentric dilation[4].
Endotracheal intubation and tracheostomy both have clear advantages and disadvantages[5,6]. The choice of technique needs to be individualized for the patient in question[7]. Percutaneous tracheostomy has been advocated as a safe and efficient bedside alternative for open tracheostomy[8-10]. Clearly, it is important to analyze the specific complications associated with percutaneous tracheostomy using different techniques. Most of these complications are mild and easy to overcome, but some major, life-threatening complications have been reported as well[11-13]. Several cases of emphysema (*i.e.* subcutaneous and/or mediastinal) and pneumothorax are reported. Often these complications are attributed to posterior tracheal wall laceration[13-19]. Although the pathophysiology of "malignant emphysema" was elucidated by the classic laboratory studies of the Macklins in 1944, the different mechanisms responsible for emphysema and pneumothorax after PT are often not clear[20]. The aims of this study are (1) to describe the incidence of emphysema and pneumothorax in our own series, (2) to review the literature and to postulate possible mechanisms for the observed complications, and (3) to test these possible mechanisms in a human cadaver model.

Materials and methods

Part 1: case description and review of the literature

From March 1997 to December 2002, 326 critically ill adult patients underwent PT in our ICU. One hundred and seventy-one consecutive PTs were performed using the GWDF technique[21]. As from February 2000, the CDT procedure became our method of choice, since then 155 PTs have been performed using this technique[22]. Six patients underwent PT using the PercuTwist technique[23]. The GWDF technique was carried out at the bedside in the ICU according to a standard protocol[21]. In short, after local infiltration, a transverse incision was made through the skin and subcutaneous tissues. The trachea was punctured with a cannulated needle below the level of the cricoid cartilage, aiming for the interspace between first and second or second and third tracheal rings. The guide wire was inserted through this cannula. The position and depth of the tracheal puncture as well as the position of the guide wire were routinely checked with a fiberscope in all patients. The forceps was advanced along the guide wire and used to dilate the tracheal wall in two steps, the first to dilate the pretracheal tissues, the second to dilate the tracheal wall. Finally, the tracheostomy tube was introduced and connected to the ventilator; the correct position was confirmed by capnography.

The CDT procedure is basically the same as the GWDF procedure except for the final stages[22]. A curved Crile's forceps was used for careful blunt dissection of the cervical fascia anterior to the trachea. Subsequently, the trachea was punctured with an introducer needle and the guide wire was threaded through the catheter. A small dilator was used to predilate the puncture canal. The conic dilator was mounted on a guiding catheter and advanced into the trachea. A Shiley tracheostomy tube was fitted over the 28 French loading dilator and advanced into position.

Patient demographics were recorded at the time of the procedure using a standard form. The cases of emphysema and pneumothorax were analyzed for peri-operative difficulties that may have resulted in these complications. Emphysema was defined as per- or post-operative presence of a palpable or radiological visible amount of air in the subcutaneous tissues or the soft tissues of the mediastinum. Pneumothorax was defined as postoperative presence of air in the pleural space.

A PubMed search was performed in the literature from 1986 to 2003 using the key words: "percutaneous", "tracheostomy", "complications", "pneumothorax" and "emphysema". Sometimes, several consecutive reports by one group were published[24-26]. In such instances, only the most recent study was taken into account. Citations were limited to human studies. We formulated a number of hypotheses concerning the mechanisms responsible for the development of emphysema and pneumothorax as complications of PT.

Part 2: analysis of mechanisms causing emphysema and pneumothorax

(A) The way in which air might spread through the paratracheal tissues was investigated. First, the anatomy of this region of the neck and its fascial planes were reviewed. The neck region in human cadavers was then dissected to examine the most important anatomical structures and cervical compartments. In a human cadaver model we simulated air leakage into the pretracheal space. For this purpose, we used a cannulated 14 G needle connected to an oxygen cylinder. The same experiment was repeated to examine whether air leakage into the retrotracheal space occurred when an incision was made through the mucosa of the posterior tracheal wall.

(B) We suspected that, with an insufflated cuff, the only way that air might leak proximally to the cuff was via the space between the inner and outer cannula of a fenestrated tracheostomy tube. The fenestrated cannula was photographed at a magnitude of 40x (Panasonic Digital Camera, WV-CD-110, Matsushita Electric Co Ltd, PO Box 288, Osaka 530-91, Japan, mounted on an Olympus microscope, TNO Eindhoven, The Netherlands) and the outer diameter of the internal cannula and the inner diameter of the external cannula were measured using a coordinate measuring apparatus (Zeiss UMC 550S, Carl Zeiss, Oberkochen, 73446 Germany). This machine contains a sensor that measures the spatial coordinates of a given object. Each 0.1 mm, it measures a coordinate of the circumference of a round object. Its accuracy is +/- 1.3 μm.

(C) We measured air leakage through the fenestration of a fenestrated tracheostomy tube, containing a non-fenestrated inner cannula, at different pressure control (PC) and

positive end expiratory pressure (PEEP) levels. The cannula was directly connected and sealed with petroleum jelly to the artificial lung. The air leakage through the fenestration was confirmed by the observation of bubbles after application of a soap solution. We used a Siemens 300-ventilator (Siemens-Elema AB, 171 95 Solna, Sweden) connected to an artificial lung, the difference between inspiratory and expiratory volume was registrated during 10 respiratory cycles for each level of pressure control and PEEP. Data are presented as mean ± S.D.

(D) The anatomical relations between the trachea and the pleural cavities were investigated in human cadavers. We simulated a situation in which a cannulated needle passes in the midline through the trachea, perforates the posterior tracheal wall and ends into the pleural cavity. Next, the neck region was dissected to inspect the anatomical structures that had been passed or damaged. Subsequently, a human cadaver was frozen, cut into 0.5 cm thick slices and photographed to establish the topographic relations between the trachea, the paratracheal structures and pleural cavities.

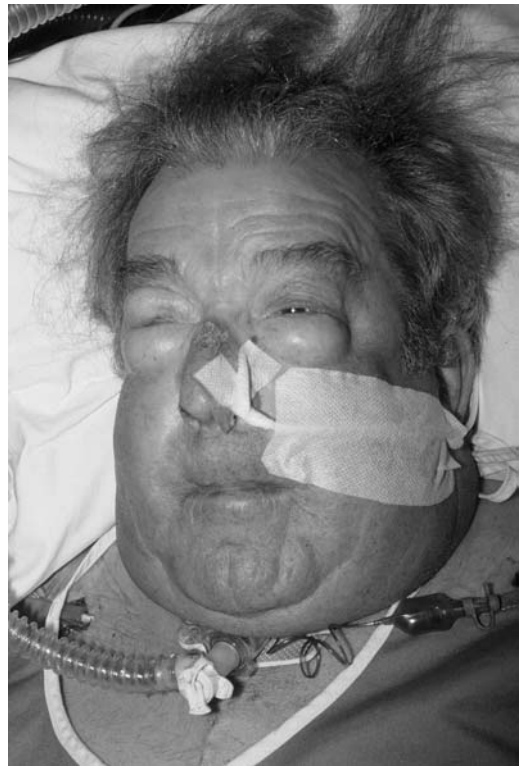
Results

Part 1: case description and review of the literature

Patient 1

A percutaneous tracheostomy was performed in a 73-year old patient, 15 days post-cardiac surgery, using the GWDF technique. Dilation of the trachea was performed with difficulty; after three attempts, the tracheostomy tube could finally be inserted. Several hours postoperatively, the patient developed extensive subcutaneous emphysema as seen in figure 1. Chest X-rays showed air around the arch of the aorta, indicating mediastinal emphysema. The subcutaneous emphysema resolved spontaneously within five days and no other problems related to the procedure occurred.

Figure 1. Subcutaneous emphysema in patient 1. Printed with permission.



Patient 2

A 74-year old woman was admitted to the ICU after extensive abdominal surgery. Percutaneous tracheostomy was performed after 11 days using the GWDF technique. The guide wire dislocated out of the trachea during forceps dilation. Subsequent insertion of the tracheostomy tube was not possible. We repeated the procedure and this time it was completed without further complications. A fenestrated Shiley size 6.0 Low Pressure Cuffed (LPC) tracheostomy tube was inserted. Immediately after the procedure, chest X-rays showed signs of subcutaneous emphysema and an unclearly defined mediastinum, compatible with mediastinal emphysema. As there was no progression of the emphysema, no further intervention was indicated. The subcutaneous emphysema resolved spontaneously within three days and no other procedure-related complications occurred.

Patient 3

A 67-year old man developed a cardiac tamponade after placement of a pacemaker. He was admitted to the ICU. Three weeks later a percutaneous tracheostomy was performed using the CDT technique. After dilation of the trachea, a fenestrated Shiley size 8.0 LPC tracheostomy tube was inserted. The procedure was performed without difficulty. After two hours, the patient developed massive subcutaneous emphysema of the head, neck and thorax. The tracheostomy tube was replaced by an non-fenestrated cannula without difficulties. The patient died two days later after a cardiac arrest, not likely related to the PT procedure. Permission for autopsy could not be obtained.

Patient 4

A 56-year old woman was admitted to the ICU after subarachnoid hemorrhage. Percutaneous tracheostomy was performed after 13 days using the GWDF technique. The trachea was punctured twice to achieve optimal intratracheal localization. Dilation of the trachea was performed without difficulty and the tracheostomy tube was inserted. The patient was weaned from mechanical ventilation and nine days later the tracheostomy tube was replaced by a fenestrated cannula. Insertion of the new tracheostomy tube proved difficult. A fenestrated Shiley size 6.0 LPC tracheostomy tube was inserted. In the middle of the night, suction through the tracheostomy tube suddenly appeared impossible. The next day a bronchoscopy was done, but it was not possible to pass the tracheostomy tube because of obstruction. A CT scan was made, which showed a pretracheal localization of the tracheostomy tube and subcutaneous emphysema of the neck. The tracheostomy tube was put into place again and intratracheal localization was verified. The subcutaneous emphysema resolved shortly after. Apparently, the patient was able to breathe past the malpositioned tracheostomy tube.

Patient 5

A 67-year old man was admitted to the ICU after cardiac surgery. Percutaneous tracheostomy was performed after 24 days using the CDT technique. Because of obstruction due to excessive mucus production, the tracheostomy tube had to be replaced frequently. On the twentieth day following the first procedure, the tracheostomy tube was replaced by a fenestrated Shiley size 8.0 LPC tracheostomy

tube. We experienced some difficulty placing the new tube. It was successfully inserted at the third attempt. When the patient was connected to the respirator, ventilation proved impossible. Because the patient was breathing spontaneously, he was given oxygen via the tracheostomy cannula, but he desaturated gradually. Subsequently, he was ventilated with a Waters set. He instantaneously developed subcutaneous emphysema of the neck. The fenestrated tube was replaced by a non-fenestrated one of size 6.0. The emphysema subsided after two days. No other procedure-related complications occurred.

Patient 6

A 26-year old woman had been involved in a high-energy acccident and was admitted to the ICU. A percutaneous tracheostomy was performed after seven days, using the CDT technique. A Shiley size 8.0 LPC tracheostomy tube was inserted. A chest X-ray made immediately after the procedure showed a right-sided pneumothorax. Bronchoscopy showed no lesions of the posterior tracheal wall and there was no significant bleeding. A chest tube was inserted. No other procedure-related problems occurred.

Patient 7

A 74-year old man who had undergone extensive abdominal surgery was admitted to the ICU. He developed complications resulting in prolonged ventilatory dependency. A percutaneous tracheostomy using the CDT technique was performed after 20 days without any difficulty or significant bleeding. A fenestrated Shiley size 8.0 LPC tracheostomy tube was inserted. After a couple of hours the patient developed increasing respiratory failure and an asystole due to a left-sided tension pneumothorax. After insertion of a thoracic drain, the patient stabilized. Bronchoscopy showed a blood clot in the left main stem bronchus, although there were no signs of active bleeding. Possibly the blood clot functioned as a one-way valve resulting in high airway pressures and subsequent pneumothorax. There were no signs of tracheal damage. Because the tracheostomy caused persisting blood loss, the next day it was decided to examine the tracheostomy site in the operating room. This examination revealed that the percutaneous tracheostomy had actually penetrated the cricothyroid membrane. Therefore, a surgical tracheostomy was performed.

Table 1. Review of the literature: incidence of emphysema and pneumothorax after PT and causative mechanisms.

Author	*n*	Description of	Proposed mechanism
Ambesh et al., 2002[27]	60	Subcutaneous emphysema (5.0% =3) Pneumothorax (1.7% =1)	Transverse mucosal lacerations Rupture emphysematous bulla
Cantais et al., 2002[29]	53	Subcutaneous emphysema (1.9% =1)	Lesion posterior tracheal wall
Fikkers et al., 2002[21]	100 (+55)	Subcutaneous emphysema (1.3% =2) Pneumothorax (1.3% =2)	See present article.
Fikkers et al., 2002[22]	171	Subcutaneous emphysema (1.8% =3)	See present article.
Byhahn et al., 2000[14]	50	Pneumothorax (2% =1)	Perforation of the posterior tracheal wall.
Escarment et al., 2000[31]	162	Subcutaneous emphysema (0.6% =1) Pneumothorax (3.0% =5)	Paratracheal placement of the tracheostomy tube.
Hinerman et al., 2000[37]	50	Pneumothorax (2% =1)	Unclear. No signs of tracheal wall laceration.
Kearney et al., 2000[26]	824	Subcutaneous emphysema (0.2% =2) Pneumothorax (0.5% =4)	Dislocation of tracheostomy tube.
Lin et al., 2000[15]	134	Pneumomediastinum (2.2%=3)	Tear posterolateral tracheal wall.
Massick et al., 2000[38]	97	Pneumothorax (2.1% =2)	No explanation.
Velmahos et al., 2000[16]	100	Cervical emphysema (4.0% =4) Pneumothorax (1.0%=1)	Posterior tracheal wall-damage and dislocation of cannula.
Moe et al., 1999[35]	130	Subcutaneous emphysema (0.7% =1) Pneumothorax (0.7% =1)	No explanation. Barotrauma due to High Frequency Jet Ventilation
Trottier et al., 1999[18]	24	Subcutaneous emphysema (12.5%=3) Pneumothorax (12.5 %=3)	Tear in posterior tracheal wall. (same patients)
Walz et al., 1998[39]	337	Subcutaneous emphysema (0.9 % =3)	Mediastinal placement of the tracheostomy tube. Reintubation not possible. Patient died.
van Heurn et al., 1996[28]	150	Subcutaneous emphysema (1.3% =2)	Multiple punctures of the trachea, tearing of the intercartilagenous tissue next to the cannula.[40]
Cole et al., 1994[41]	55	Subcutaneous emphysema (3.6% =2)	No explanation.

Table 1. (continued).

Author	*n*	Description of	Proposed mechanism
Friedman et al., 1993[42]	100	Subcutaneous emphysema (4.0% =4) Pneumothorax (1.0% =1)	Difficulties in changing the tracheostomy tube.
Ciaglia et al., 1992[43]	170	Subcutaneous emphysema (1.2% =2)	No explanation
Ivatury et al., 1992[44]	55	Subcutaneous emphysema (2.0% =1) Pneumothorax (3.6% =2)	High ventilatory pressures
Schachner et al., 1989[45]	80	Subcutaneous emphysema (2.5% =2)	No explanation.
Hazard et al., 1988[30]	55	Subcutaneous emphysema (3.6% =2) pneumothorax (1.8% =1)	Possibly perforation or tear in posterior tracheal wall.

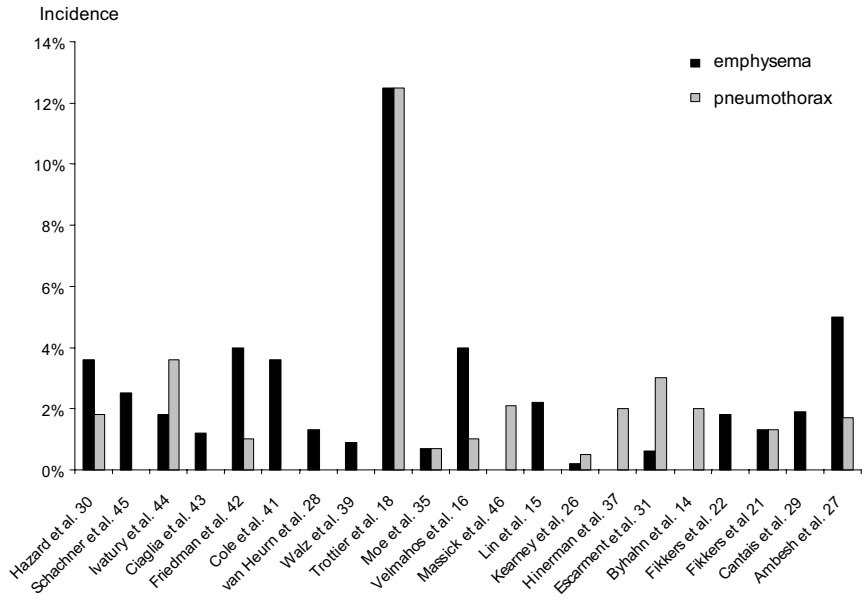
Table 2. Review of the literature: emphysema and pneumothorax after PT and causative mechanisms in *case reports*.

Author	Description of	Proposed mechanism
Kaylie et al., 2002[13]	Subcutaneous emphysema (*n*=1)	Tear in posterior tracheal wall caused by tracheostomy tube-introducer.
Mostert et al., 2001[34]	Subcutaneous emphysema (*n*=1)	Fenestrated tube, extraluminal localization of the fenestration.
Douglas et al., 1999[17]	Cervical emphysema (*n*=2)	Laceration of posterior tracheal wall. Damage by the tip of the tracheostomy tube-introducer.
Fraipont et al., 1999[46]	Pneumoperitoneum (*n*=1)	Tear in posterior tracheal wall
Malthaner et al., 1998[47]	Pneumothorax (*n*=2)	Tear in posterior tracheal wall
Sun, 1996[48]	Subcutaneous emphysema (*n*=4) Emphysema and pneumothorax (*n*=1)	Air leaks into the cervical tissues during cannulation procedure
Fish, 1996[12]	Tension pneumothorax (*n*=1)	Tear in posterior tracheal wall.
Noden et al., 1995[33]	Pneumothorax (*n*=1)	Direct placement of tracheostomy tube in pleural cavity.
Wang et al., 1992[19]	Pneumothorax (*n*=2)	Direct placement of tracheostomy tube in anterior mediastinum. Perforation of posterolateral tracheal wall, placement of tube tip in tracheo-esophageal groove.

Review of the literature:

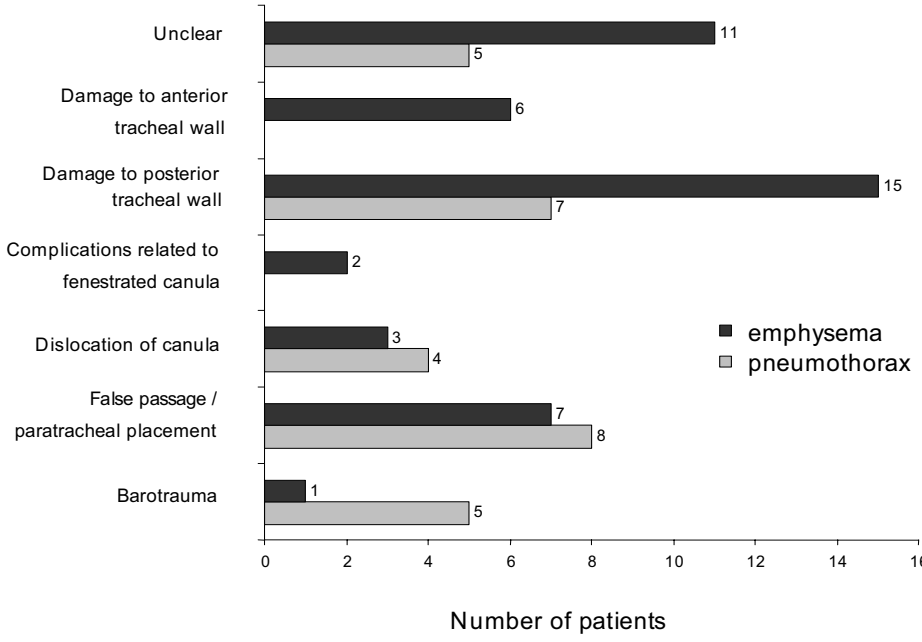
Our review of the literature showed a total of 21 series, including 3,012 patients (Table 1). The incidence of subcutaneous emphysema was 1.4% (41 cases) and of pneumothorax 0.8% (25 cases). Furthermore, nine case reports were reviewed including ten patients with subcutaneous emphysema and six patients with pneumothorax (Table 2). The incidences of subcutaneous emphysema and pneumothorax are presented in Figure 2.

Figure 2. Incidence of emphysema and pneumothorax.
The x axis depicts the first author of the publication.
The y axis depicts the incidence of emphysema (black) and pneumothorax (gray).



In the series of Trottier et al.[18] the incidence of pneumothorax with accompanying emphysema was unexpectedly high, leading to a quality improvement program. Proposed mechanisms for emphysema and pneumothorax after PT are presented in Figure 3. All these mechanisms lead to air leaking from the trachea into the subcutaneous tissues.

Figure 3. Proposed mechanisms of emphysema and pneumothorax in the reviewed literature. The x axis depicts the number of patients. The y axis depicts the proposed mechanism of emphysema (black) and pneumothorax (gray) suggested in a given publication.



Air then will track along the path of least resistance. In sixteen cases the exact mechanisms for the development of emphysema and pneumothorax were not described or unclear. Three publications, including six patients, mentioned damage to the anterior tracheal wall as a possible mechanism for the development of subcutaneous emphysema[22,27,28]. Ambesh et al. described three cases in which the tracheal circumference was split after PT using the GWDF technique, resulting in subcutaneous emphysema[27]. Van Heurn et al. related subcutaneous emphysema to multiple punctures of the trachea and tearing of the intercartilagenous tissue adjacent to the cannula[28]. Excessive dilation of the anterior tracheal wall also increases the risk of emphysema. Seven publications, dealing with fifteen patients, attributed emphysema to posterior tracheal wall laceration[13,15-18,29,30]. Four publications, dealing with seven patients, mentioned posterior tracheal wall laceration resulting in pneumothorax[12,14,16,18]. Injury to the posterior tracheal wall might be caused by improper stabilization of the guidewire

and guiding catheter, allowing them to move along the posterior tracheal wall[18]. Another mechanism of damage to the posterior tracheal wall is laceration by the tip of the tracheostomy tube introducer[17]. Dislocation of the tracheostomy tube, false passage, or paratracheal placement resulting in emphysema and pneumothorax are described in seven publications, concerning 22 patients[19,21,22,26,31-33]. Only two cases have been described in which emphysema was related to a fenestrated tube, due to extraluminal localization of the fenestration[21,34]. Four publications, concerning five patients, explained the development of pneumothorax as a result of barotrauma[21,27,35,36].

Part 2: Analysis of mechanisms for the development of subcutaneous emphysema and pneumothorax.

(A) Cadaver model 1: Air leakage through the anterior tracheal wall.

We performed a percutaneous tracheostomy in a human cadaver, using the CDT technique. The cannula was withdrawn and small-sized oxygen tubing was placed in the pretracheal subcutaneous tissues. Air was able to spread along the cervical planes without difficulty. In a matter of minutes subcutaneous emphysema developed extending from the cervical area to the head and thorax. This resembled the presentation as described in the case of the first patient.

Cadaver model 2: Air leakage through the posterior tracheal wall.

We performed a percutaneous tracheostomy in a human cadaver, using the CDT technique. The cannula was withdrawn and a two-centimeter, vertical transmucosal incision was made in the posterior tracheal wall. The tracheostomy tube was re-introduced with the insufflated cuff occluding the tracheostomy opening. Finally, a cuffed endotracheal tube was placed in order to secure the proximal airway. In this way we ensured that the mucosal incision was distal to the cuff and air leakage through the anterior defect was prevented. When the tracheostomy tube was connected to a Waters set, subcutaneous emphysema suddenly appeared after an interval of several minutes, much in the same way as in cadaver model 1. After this experiment, the trachea was further opened. The incision in the posterior wall had widened as if it had been dissected by the positive ventilation pressure.

(B) Measurement of cannula diameters

The outer diameter of the internal cannula was 9.22 mm with a variation of 0.056 mm and the inner diameter of the external cannula was 9.35 mm with a variation of 0.07 mm. The average distance between the internal and external cannula was 0.13 mm (Figure 4).

Figure 4. Photograph of outer and inner cannula. Magnitude 40x.
Arrow indicates space between outer and inner cannula.

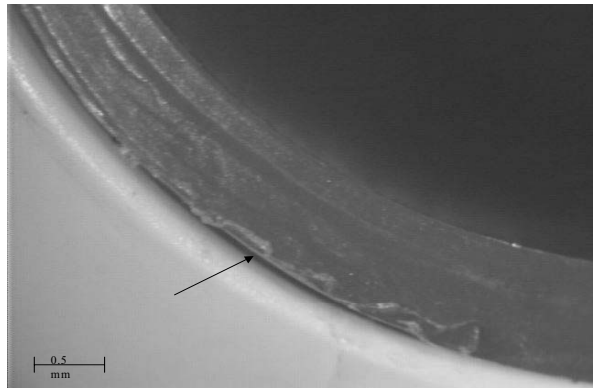
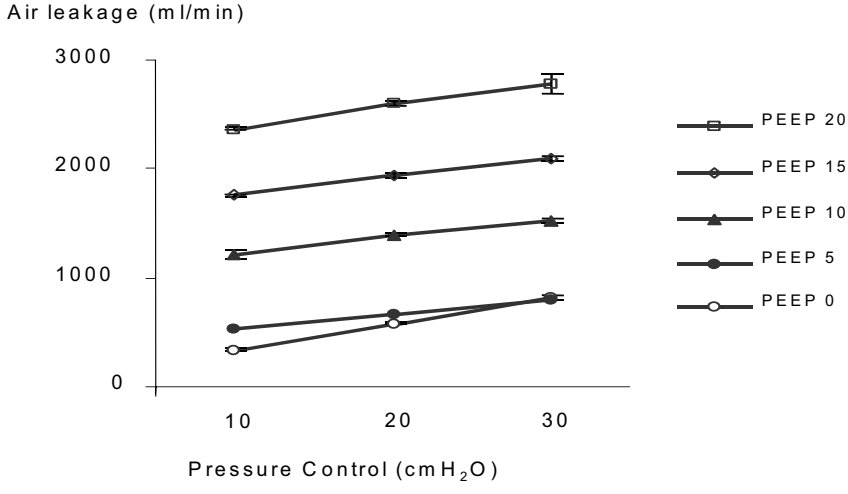


Figure 5. Air leakage through a fenestrated outer cannula with a non-fenestrated inner cannula measured as the difference of inspiratory and expiratory volume at different PEEP and PC levels at a respiratory rate of 15/minute. Mean ± S.D. of ten observations.



(C) Air leakage through the fenestration

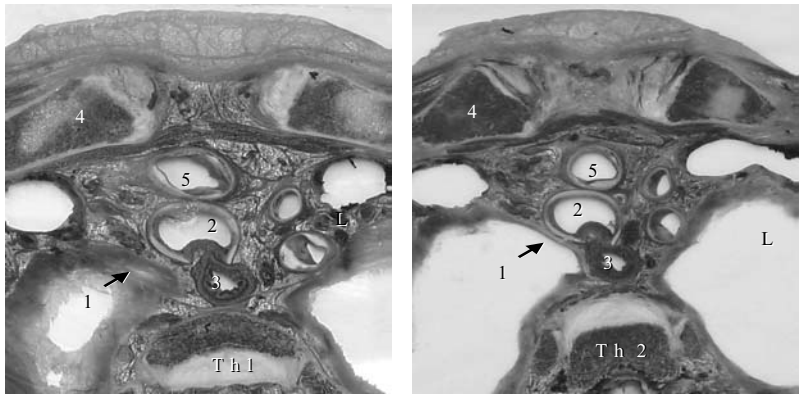
The results of our measurements in a model of air leakage through the fenestration of a tracheostomy tube at different PC and PEEP levels were impressive. Air loss was more pronounced at higher levels of PC and PEEP. At PC 30 and a PEEP of 20 cm H_2O, the air loss was 2780 ± 85 ml/min (Figure 5).

(D) Cadaver model 3: Pneumothorax

In a human cadaver, with the lungs removed, we performed a midline puncture with a cannulated needle as in a standard PT procedure. We perforated the posterior tracheal wall and, although the introduction of the needle was almost vertical, it was fairly easy to reach the pleural cavity. During subsequent dissection of the pre-tracheal space, we confirmed that the needle passed through the anterior tracheal wall into the tracheal lumen and through the posterior tracheal wall, finally ending in the pleural cavity. This model shows that, even when puncturing the trachea in the midline, the tip of the needle can puncture the pleural cavity. This also shows that the pleural dome may extend in the neck posterolaterally to the tracheal wall (Figure 6).

We believe that this is also the area where posterior tracheal wall puncture or laceration is most likely to occur, especially when the puncture site is lower than usual. The distance between the dorsal tracheal wall and the pleural cavity also decreases in the distal slices. In our cadaver model, this distance was about five millimeters.

Figure 6. Cross-sections at the level of Th1 and Th2 (N.B. the cricoid cartilage is located at the level of C6). 1. Pleural cavity, 2. Trachea, 3. Esophagus, 4. Clavicle, 5. Brachiocephalic trunc.



Discussion

In our own experience and according to the existing literature, the incidence of emphysema and pneumothorax after PT is rather low[21,22]. We demonstrated that it is possible to induce subcutaneous emphysema via an anterior or a posterior tracheal lesion in a cadaver model. It is also possible to reach the pleural cavity after a midline dorsal puncture, possibly resulting in pneumothorax. Finally, in our series, complications were associated with a difficult PT procedure and the use of a fenestrated cannula.

A literature search (Table 1) showed that 1.4% of patients with a PT acquired emphysema, and 0.8% of patients with a PT had a pneumothorax. Although several mechanisms may explain the development of emphysema, it can only develop after an air leak occurring somewhere in the respiratory tract[49]. Air then will track along the path of least resistance[50]. As long as there exists a tracheal defect without a route for air to escape via the skin, air will track along subcutaneous tissue and fascial planes into the neck, face, pharynx, chest wall, mediastinum, and pleural cavity. By this mechanism, anterior tracheal wall lesions may cause subcutaneous emphysema. This may happen when positive pressure ventilation via the endotracheal tube is continued after PT (and after the cuff of the tracheostomy cannula is insufflated) or by dislocation of the tracheostomy tube[26,31,39,40,51,52]. Multiple punctures and excessive dilation of the trachea during the procedure will also increase the risk of peristomal air leakage through the anterior tracheal wall. Even in seemingly uncomplicated cases, extensive mucosal and cartilaginous damage may be present, with bidirectional mucosal tears beyond one tracheal ring flanking the stoma[53]. Tears in the posterior tracheal wall can be caused by the tip of the loading catheter, if the guide wire and guiding catheter are not properly stabilized, allowing them to move along the posterior tracheal wall[17,18]. During PT using the GWDF technique, the tip of the dilating forceps could damage the posterior tracheal wall[27,54]. Finally, the use of a fenestrated cannula can cause subcutaneous emphysema, when the fenestration is wholly or partially located outside of the tracheal lumen, allowing air to leak through the fenestration into the pretracheal space[34].

Our findings suggest that the most important location of air leakage after PT is through the anterior tracheal wall, although air leakage through a posterior tracheal wall perforation is also possible. We hypothesized that air leakage through a fenestrated

cannula could be responsible for the development of subcutaneous emphysema. To test this hypothesis, we measured the air leak of the space between the non-fenestrated inner cannula, and fenestrated outer cannula and found impressive and progressive air leakage with increasing ventilatory pressures. This narrow slit (0.13 mm) was enough to allow air to pass between the internal and external cannulas, and finally pass through the fenestration. Subcutaneous emphysema developed in a matter of minutes. We believe that, in patients who have a fenestrated cannula, the most important mechanism for development of emphysema is air leakage between the inner and outer cannula. Therefore, these cannulas should not be used primarily after PT. It is clear from our experiments and form the literature that subcutaneous emphysema can also be caused by posterior tracheal wall laceration. Air finds its way along the trachea ventrally and thus causes subcutaneous emphysema in the neck and facial region, although a delay in the occurrence of subcutaneous emphysema was noted in our experiments.

Concerning the mechanism of pneumothorax after PT, we found that even when puncturing the trachea in the midline, the tip of the needle can still puncture the lung. This can be explained by the fact that the pleural cavity is not limited to the lateral regions of the trachea, but extends around the lateral tracheal wall to the posterior tracheal wall. Because of the short distance between the dorsal tracheal wall and the pleural cavity the lungs can easily be punctured during the PT procedure, when the posterior tracheal wall is lacerated or punctured. The risk of puncturing the lung increases when the puncture site is lower. Moreover, in patients with chronic obstructive pulmonary disease, the risk of puncturing a lung is higher because of a higher pleural dome. Another possible mechanism of pneumothorax after tracheal air leak might be the occurrence of pneumomediastinum followed by air leak through the mediastinal pleura.

In conclusion, emphysema and pneumothorax are relevant, but infrequent complications of PT. Understanding the causative mechanisms will help preventing these complications. Fenestrated cannulas should not be used immediately, but, if required, only after a week, when the tracheostomy wound has healed sufficiently. Avoiding perforation of the posterior tracheal wall can prevent pneumothorax.

Bronchoscopy is invaluable in this respect, as it may help to avoid puncture of the posterior tracheal wall.

Acknowledgements

The authors whish to thank W.A.J. van den Eijnden, BSc (TNO, Eindhoven, The Netherlands) for providing the measurements of the cannula.

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Chapter 6

Emergency cricothyrotomy: a randomised crossover trial comparing a wire-guided and a catheter-over-needle technique

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Anaesthesia 2004; in press

Summary

In a randomised crossover trial, we compared a wire-guided cricothyrotomy technique (Minitrach) versus a catheter-over-needle technique (Quicktrach) in terms of performance time, ease of method, accuracy in placement and complication rate. Ten anaesthesiology and ten ENT residents performed cricothyrotomies with both techniques on prepared pig larynges. The catheter-over-needle technique was faster than the wire-guided (48 versus 150 seconds, $p<0.001$) and subjectively easier to perform (VAS-score 2.1 versus 5.6, $p<0.001$). Correct position of the cannula could be achieved in 95% and 85% respectively (NS). There was one complication in the catheter-over-needle group compared to five in the wire-guided group.

We have concluded that the wire-guided minitracheotomy kit is unsuitable for emergency cricothyrotomies performed by inexperienced practitioners. On the other hand, the catheter-over-needle technique appears to be safe and reliable.

Introduction

Cricothyrotomy is a surgical intervention intended to gain control of an airway that cannot otherwise be accessed in an emergency situation[1,2]. It is therefore the final step in the difficult-airway algorithm of the ASA (American Society of Anesthesiologists)[3]. If performed correctly, it is a quick and essential lifesaving-skill. However, most physicians involved in airway management have only very limited experience with this technique, since it is rarely used and if used, it nearly always involves a chaotic situation. Recent studies do not demonstrate a significant difference in procedure time and complication rates between the conventional (surgical) approach and the techniques that make use of the Seldinger method[4,5]. Catheter-over-needle cricothyrotomy seems to be a fast procedure and easy to execute[6,7]. This study evaluates and compares the procedure time, reliability and peri-operative complications of two techniques frequently used for emergency cricothyrotomy, the wire-guided (Minitrach) and the catheter-over-needle (Quicktrach) procedures[7-9].

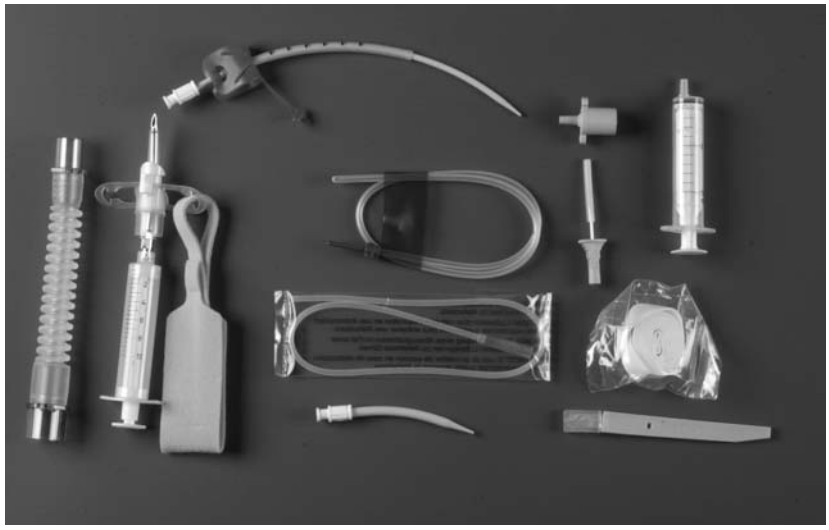
Methods

In this randomized crossover trial, residents from the University Medical Centre Nijmegen performed cricothyrotomies by using both the wire-guided and catheter-over-needle technique. Larynges from freshly slaughtered pigs were collected. Each larynx was freed of prelaryngeal tissues and covered with a piece of thinned pigskin, stapled on a wooden board and positioned with the cricothyroid membrane upwards (Figure 1). The cranial side of the airway was marked. We simulated an emergency setting in two operation theatres. The participants' years of training and previous cricothyrotomy experience were recorded. One month previously, all participants received a ten-minute presentation about the difficult-airway algorithm of the ASA and the two cricothyrotomy-sets. Afterwards, they practised both methods on a pig's larynx in the same theatre setting.

Figure 1. Participant using Quicktrach on a pig larynx covered with a piece of thinned pigskin, stapled on a wooden board.

Participants were randomly allocated to perform either one of two cricothyrotomy techniques first. In one operation theatre, cricothyrotomy via the wire-guided technique was used, in the other the catheter-over-needle technique. The wire-guided group used a Mini-Trach II Seldinger kit (SIMS Portex Ltd, UK), consisting of a needle, a syringe, a guide wire, a dilator and a cannula no. 4 (Figure 2, right).

Figure 2. Quicktrach set on the left. Mini-Trach II Seldinger kit on the right.



The catheter-over-needle group used a Quicktrach (VBM Medizintechnik GmbH, Germany), consisting of a conical shaped needle, a plastic cannula no. 4 and a stopper (Figure 2, left). The stopper prevents the needle from being inserted too deeply and therefore reduces the risk of posterior tracheal wall perforation. Participants were allowed to make a stab incision before puncturing.

After the first procedure, participants were crossed over to perform the alternate technique on a different larynx. Every attempt was timed by an assistant and registered on a standard form. Two time intervals were defined: the period of time between the inspection of the instruments and the first incision, and the time from incision until the first artificial ventilation. Each attempt ended with the start of ventilation or when reaching a time limit of 240 seconds. This arbitrary limit was determined by consensus among the investigators after reviewing the literature[4,10], in which three minutes is considered the maximum accepted time to complete cricothyrotomy in case of total airway obstruction. We allowed the participants one minute extra. Exceeding this limit was considered a failure. All instruments required were easily accessible and placed within reach of the participant. Immediately after each attempt, the participants were asked to indicate the ease of the procedure on a Visual Analogue Scale (0: very easy; 10: very difficult). Finally, a member of the ENT staff opened the larynx and trachea. This allowed complete inspection of the laryngeal structures, determination of the correct position of the cannula and evaluation for any damage. Exact localisation of the puncture and complications, including fracture of cricoid/thyroid or trachea, injury of the posterior tracheal wall, pre-, para- or post-tracheal localisation of the cannula and guide wire kinking, were registered on a standard form. After performing both procedures, participants were asked for their method of preference.

Twenty physicians were needed to detect a 60 second time difference with 90% certainty, based on data from the practice session. We randomly selected ten anaesthesiology residents and ten ENT residents. Data are provided as mean values (SD) or numbers (%). Continuous variables were compared with Student's T-test. Fisher's exact test was used to compare success rates and complications. A cut-off level < 0.05 was accepted as statistically significant.

Results

The participants had 2.8 years of postgraduate training on average. They had little or no previous cricothyrotomy experience. The measured time intervals, ease of method and position of the cannula are listed in Table 1.

Table 1. Preparation time, total time (seconds), ease of method (VAS-score) and success rate. Values are means ± SD or numbers (%).

	wire-guided (*n*=20)	catheter-over-needle (*n*=20)	*p*-value
Preparation time (sec)	20.8 ± 8.8	13.3 ± 6.0	0.007
Total time (sec)	149.7 ± 44.2	47.9 ± 19.6	< 0.001
Ease of method (VAS-score)	5.6 ± 2.7	2.1 ± 1.8	< 0.001
Correct position of cannula	17 (85)	19 (95)	NS

Correct placement of the cannula could be achieved in 17 attempts (85%), using the wire-guided technique, and 19 attempts (95%), using the catheter-over-needle technique. In the first group, one failure, i.e. pre-tracheal placement of the cannula, was due to incorrect puncture. On two other occasions, the guidewire perforated the posterior tracheal wall, resulting in one aborted attempt and one post-tracheal placement of the cannula. The one failure in the catheter-over-needle-group resulted from pre-tracheal placement. Complications are summarized in Table 2.

Table 2. Complications.

	wire-guided (*n*=20)	catheter-over-needle (*n*=20)
Injury to posterior tracheal wall[1]	4	0
cricoid/thyroid/tracheal cartilage injury	0	0
Pretracheal placement	1	1
Paratracheal placement	0	0
Total	5	1

[1] Including one case of post-tracheal placement

Most complications were registered in the wire-guided group (five versus one in the catheter-over-needle group). However, this difference was not significant. When asked for their preferred method of use in a real emergency situation, 90% of the participants favoured the catheter-over-needle technique.

Discussion

We compared the success rate, complication rate and insertion time of two emergency cricothyrotomy techniques, the wire-guided (Mini-Trach II) and the catheter-over-needle cricothyrotomy (Quicktrach). The main finding of this study is that the catheter-over-needle procedure can be performed faster, easier, with a higher success rate and with fewer complications than the wire-guided technique.

Several studies using a wire-guided technique have been published[4,5,7,10,11]. Recently, Vadodaria et al. compared four different cricothyrotomy kits in a human simulator[7]. They found a 100% success rate of establishing an adequate airway within acceptable time limits using the catheter-over-needle (Quicktrach) and wire-guided (Melker) sets (51 and 38 seconds respectively). Damage to the posterior tracheal wall was registered twice with both techniques. Although their participants were more experienced than the ones in our study, it is rather surprising that the wire-guided technique (involving more steps) proved faster than the catheter-over-needle technique. Eisenburger et al. compared wire-guided versus standard surgical technique in human cadavers[4]. The cricothyrotomy times were respectively 100 and 102 seconds; incidence of injuries was not significantly different (10% versus 15%). Chan et al. did a similar study[5]. No differences in complication rates (in one and two cases respectively) or performance time (75 and 73 seconds respectively) were found. The first study investigating the use of the Quicktrach showed that the time until the cannula was positioned properly was significantly shorter when an incision was made prior to the puncture (35 versus 83 seconds)[6]. There was a 31% complication rate. These varied from 4% serious complications, i.e. para-tracheal placement, to 27% minor ones, i.e. injuries to thyroid, cricoid, tracheal cartilage or soft tissues.

In our study, the procedure times and complication rate of the wire-guided technique were relatively high. There were several explanations. First, wire-guided cricothyrotomy involves several discrete steps that must be performed in the proper sequence to be successful. Some participants forgot crucial steps, such as removing the needle before feeding the dilator onto the guidewire. Second, some participants accidentally pulled out the guidewire too early and were forced to start all over again. Third, because the needle tip of the minitracheotomy kit is blunt, the initial puncture needed to be perfectly in the midline. Otherwise, the needle would often remain in a submucosal position, tenting but not perforating the mucosa, leading to inability to aspirate air. Fourth, in several procedures, threading the guidewire proved difficult. Because the guidewire does not have a J-tipped design, participants sometimes introduced the guidewire the other way round, resulting in perforation of the posterior tracheal wall on at least two occasions. Finally, the participants in this study were only second time performers of the procedures. It seems reasonable that more training would improve procedure times, However, one should remember that with such an infrequently performed, but complicated procedure, loss of skill over time will undoubtedly take place. We have chosen residents instead of more experienced staff, because residents are most often involved in emergency situations. They have only minimal experience with, and so were least prejudiced to, one of the procedures and were very motivated to find out the optimum technique. Due to this lack of experience, a plateau in the learning curve could hardly be reached. For this, at least five attempts were needed[12]. Because both techniques were practised one month earlier and because even for staff members cricothyrotomy is an infrequently performed procedure, we do not believe that this was a major issue.

Several aspects of the study design limit the generalisability of our conclusions. A pig cadaver is not a living human being. We acknowledge that the setting we created does not reflect the real-life situation. Although participants were put under time pressure, this is not the same as the stress of a real emergency situation. No distracting factors, like facial trauma, neck injury and restlessness of the patient were present. Obviously, active bleeding cannot be simulated in a cadaver model, nor can late complications, as infection or stenosis. However, a prospective controlled randomised trial on humans is ethically and logistically impossible. Alternatively, human corpses may be good teaching models for procedures such as cricothyrotomy[13]. Unfortunately, these are not

widely available for research in the Netherlands. Moreover, formalin prepared corpses are less realistic then fresh cadavers. Therefore, we have chosen fresh larynges from pig cadavers, covered with a piece of skin. While thinned pigskin resembles human skin more than the skin of any other animal[14], there are some slight anatomical differences between a pig's larynx and a human larynx. However, this preparation realistically represents the human neck for these purposes and seems suitable for such an experiment[14-16]. Besides, we feel that the heterogeneity of the pig larynges we used is more compatible with the real life situation, where no-intubate-no-ventilate scenarios frequently occur involving patients with the least favorable anatomy, compared to the uniform design of a human simulator. Finally, this is a cheap and practical model, which can easily be set up and used as a training device for cricothyrotomies.

Although in many hospitals the Portex minitracheotomy set is available for emergency cricothyrotomies, we feel that this set is unsuitable for this purpose when inexperienced practitioners are involved. The procedure took too long and gave rise to many complications. On the other hand, the catheter-over-needle technique proved safe and reliable.

Acknowledgements

We are grateful to J. van Egmond, PhD, for his statistical advice. We also thank B.M. Wensing, MD, for his invaluable assistance. Endomed (P.O. Box 106, 6490 AA Didam, the Netherlands) and Smiths Medical (P.O. Box 126, 5240 AC Rosmalen, the Netherlands) provided the cricothyrotomy kits. None of the authors has any interest in, or funding association with these companies.

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Chapter 7

General overview

1. Indications for percutaneous tracheostomy

Tracheostomy offers a number of practical advantages compared to translaryngeal intubation, such as a decrease in airway resistance, anatomical dead space and work of breathing, therefore improving weaning from mechanical ventilation in patients with marginal respiratory mechanics[1]; better pulmonary toilet; improved patient comfort[2]; absence of laryngeal and vocal cord injuries[3]; security of the airway; easier tube changes, and the possibility for oral nutrition and speech, which may in turn improve the patient's psychological status[2,4]. Translaryngeal intubation and tracheostomy are prone to different types of complications[3,5]. Tracheostomy is an invasive procedure with a small, but definite risk of operative mortality and morbidity. Translaryngeal intubation has related problems. The tube is not easy to secure firmly, and the agitated patient may bite it, occluding the lumen. Oral hygiene is difficult to perform adequately and angular stomatitis may occur, usually related to the securing tapes[6]. Long-term translaryngeal intubation may result in serious morbidity[7-9]. The first study to prospectively compare translaryngeal intubation to surgical tracheostomy was published in 1981[10]. The conclusion was that the complications of tracheostomy were more severe than those of translaryngeal intubation, and tracheostomy was not advised in the first three weeks of translaryngeal intubation. More recent studies[2,11], however, have established that a standard surgical tracheostomy can be performed with an acceptably low risk of peri-operative complications.

Nowadays, tracheostomy is a standard procedure in critically ill patients. Indications for surgical and percutaneous tracheostomy are identical for patients in the intensive care unit (ICU). These include relief of upper airway obstruction; protection of the tracheobronchial tree in patients at risk of aspiration; tracheal access for long-term positive pressure ventilation; and weaning from mechanical ventilation[12]. In the ICU, upper airway obstruction is most commonly seen as a direct consequence of head and neck surgery or trauma. Inability to prevent pulmonary aspiration because of diminished protective airway reflexes is seen in a multitude of patients. Prolonged weaning from mechanical ventilation is now the main indication for tracheostomy on the ICU[13]. This represents a significant change when compared with just a few decades ago[14]. This is attributable to a number of major advances in medicine: the development of vaccines for infectious obstructive diseases; the development of fibreoptic

equipment, which facilitates difficult intubation under direct visualisation; and the use of cricothyrotomy for emergency airway management (Chapter 6 of this thesis).

The reason for the increasing popularity of percutaneous tracheostomy has been its simple bedside application, ease of scheduling, avoidance of transporting critically ill patients, and its cost-effectiveness[15-20]. In general, surgical tracheostomy is performed in the operating theatre, although it is also done at the bedside[21]. Understandably, the differences in costs diminish when surgical and percutaneous tracheostomy are performed in the same setting, i.e. at the bedside on the ICU[22]. Transport to and from the operation theatre can be done safely[23], although eliminating the risk of patient transport altogether is preferable.

Because in many institutions, percutaneous tracheostomy is the method of choice[24], this means that the experience with surgical tracheostomy will decrease and is likely to be carried out on the patient in whom percutaneous tracheostomy is contra-indicated, has failed, so in less optimal circumstances[25].

2. Contra-indications for percutaneous tracheostomy

Most contra-indications are relative and depend on individual experience. Percutaneous tracheostomy is contra-indicated in patients with an infection of the anterior neck; a large goitre; a history of neck surgery; a distance from thyroid to manubrium of less then three centimetres; elevated intracranial pressure; who need an emergency airway (see Section 3); are younger than 16; and/or have a total body weight of less than 40 kg. However, several authors report that the percutaneous procedure is their preferred method in patients with a difficult anatomy[26]. Although previous tracheostomy may result in scarring, repeat procedures are not considered a contra-indication any more[27]. Due to the high elasticity of the tracheal walls in children, dilation is difficult, as the anterior and posterior tracheal wall can easily be pushed together and tracheal lesions may occur[28].

Relative contra-indications are patients with hypoxia despite intensive ventilatory support (PEEP higher than 20 cm H_2O and/or FiO_2 higher than 70%); uncorrectable coagulation abnormalities; known or expected difficult translaryngeal intubation; and obesity with inability to identify the proper landmarks (see Section 9. Special subgroups). Although hypoxia is one of the most frequent complications of

percutaneous tracheostomy[29,30], a recent prospective study showed that percutaneous tracheostomy could be safely performed in patients ventilated with high PEEP[31]. There was no evidence of long-term derecruitment. Patient selection is very important, in particular when sufficient expertise is not available.

The disadvantage of a percutaneous tracheostomy, although minimally invasive, is that it is still a procedure with risk of complications. As with translaryngeal intubation and after surgical tracheostomy, the upper airways are bypassed, warming, humidification and filtering of air do not take place before the inspired air reaches the lungs. This results in the drying out of tracheal and bronchial epithelium. Another disadvantage is the loss of intrinsic positive end expiratory pressure ($PEEP_i$), normally mediated by glottic activity. This predisposes alveolar collapse or atelectasis. This is particularly significant in chronic obstructive pulmonary disease (COPD) patients who utilise increased $PEEP_i$ as compensatory strategy for pulmonary dysfunction.

3. Emergency situations

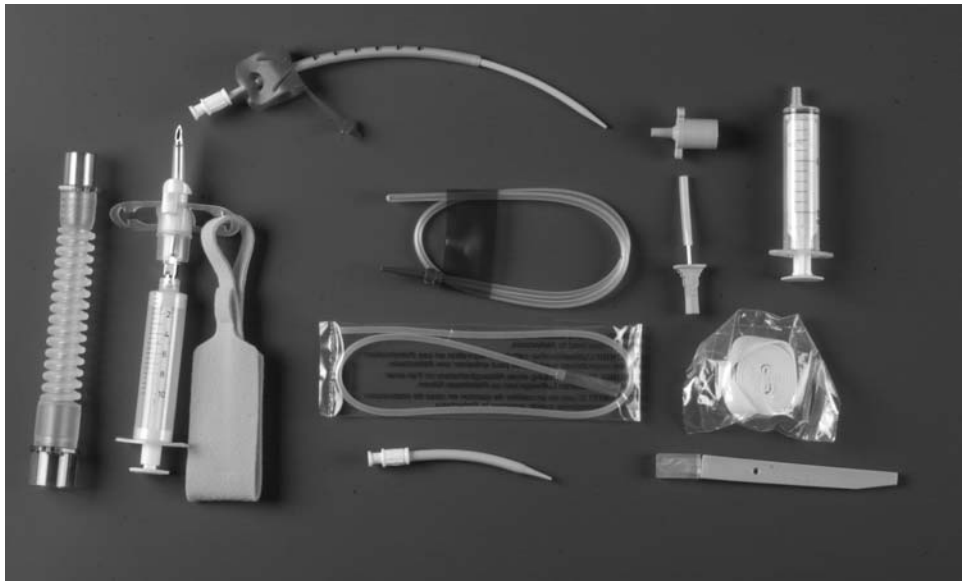
A patient who has an upper airway obstruction that cannot be relieved by positive pressure mask ventilation or by translaryngeal intubation ("cannot intubate, cannot ventilate") must have an immediate surgical airway. It is therefore the final step in the recently updated difficult airway algorithm of the ASA (American Society of Anesthesiologists)[32]. For obstruction above the level of the cricoid cartilage, a cricothyrotomy is indicated. Although there are case reports describing successful percutaneous tracheostomy in an emergency situation, in which the conic dilation[33] or the guide wire dilating forceps technique was used[34-36], cricothyrotomy is the method of choice. It is performed more easily and quickly than a tracheostomy because the cricothyroid membrane is immediately subcutaneous and its landmarks are easily identified. Only in cases of obstruction situated at the level of the cricoid cartilage or below, will a tracheostomy be necessary.

Although, in an acute situation, many physicians will use a surgical technique for emergency airway access, several commercial percutaneous kits are available, relying on the Seldinger technique (Melker emergency cricothyrotomy, Minitrach II, Figure 1), or on a catheter-over-needle technique (Nu-Trake, Quicktrach, Figure 1). Recent studies do not demonstrate a significant difference in procedure time and complication

rates between the surgical approach and the techniques that make use of the Seldinger method[37,38]. Catheter-over-needle cricothyrotomy is a faster procedure and easier to execute compared to the wire-guided Seldinger technique (see Chapter 6).

Chevalier Jackson systematised the approach to tracheostomy and clarified the important principles of its performance[39]. In 1921, he published another classic article[40]. He stressed that 'high tracheotomy should never be done', and the medical profession accepted his condemnation of cricothyrotomy. It was widely believed that chronic subglottic stenosis was an invariable consequence of this procedure. If done, rapid conversion to a standard tracheostomy was advised. In 1976, Brantigan and Grow published a large series of 655 cricothyroidotomies[41,42]. They proved that, even when in use for weeks, it is a benign and well-tolerated procedure, not significantly associated with subglottic stenosis. However, it should not be performed in the face of acute laryngeal disease, as was often the cause in the early 1900's. Even though the cricoid ring is the narrowest portion of the trachea, it is large enough to admit any standard tracheostomy tubes. With the introduction of the relative safe procedure of percutaneous tracheostomy, elective cricothyrotomy is seen less often[43].

Figure 1. Quicktrach set (left) and Mini-Trach II Seldinger kit (right).



4. Timing of tracheostomy

The decision when to perform a tracheostomy has always been controversial[3], although it is well known that the number of complications increases with an increasing duration of translaryngeal intubation[44]. Much of this controversy originates from the difficulty of accurately predicting the length of time that patients require mandatory ventilation. It may well be impossible to give sound guidelines on the timing of tracheostomy, as this depends on the clinical situation and prognosis of the patient, and not on a dogmatic time limit. The decision to convert a translaryngeal tube to a tracheostomy cannula in the ICU has to be individualised. This 'anticipating approach' takes into consideration the potential benefits of the procedure compared with prolonging translaryngeal intubation[45,46]. Before the introduction of the percutaneous technique, the length of time of translaryngeal intubation tended to be longer[5]. Because no data exist regarding the relative impact of tracheostomy in terms of patient outcome relative to prolonged translaryngeal intubation, recommendations for timing to achieve these benefits have been based on expert consensus. A consensus conference on artificial airways in 1989[47] recommended translaryngeal intubation as the method of choice for an artificial airway needed for up to ten days, whereas tracheostomy is preferred when the need for an artificial airway exceeds 21 days. However, it is a misconception that a tracheostomy within three weeks is premature. This may result in a patient undergoing a mandatory two to three weeks of translaryngeal intubation before tracheostomy is performed[48]. In fact, tracheostomy should be secured as soon as it becomes apparent that sustained independent ventilation is not likely to happen within three weeks, as for patients with irreversible neurological disorders[4] or with major trauma[49]. In patients with infratentorial lesions[50], it is proven that an aggressive policy towards early tracheostomy is justified based on the low frequency of successful extubations and high frequency of extubation failures. The decision should be made after one week of conventional ventilation. Early tracheostomy may be beneficial for ICU patients as it helps to reduce the number of days on the ventilator, ICU stay and total hospital stay[4,49,51]. However, a randomised, prospective trial failed to show any benefit of early tracheostomy[52], and a recent review concluded that there is insufficient evidence to support the hypothesis that timing changes the duration of mechanical ventilation or extent of airway injury in patients on the ICU[53]. Also, the review identified multiple flaws in the available studies (inadequate

randomisation, no description of tracheostomy and/or weaning criteria, etc.). Observational studies[4,54] indicate that the absence of clear criteria for selecting patients for tracheostomy results in considerable variation in the timing of the procedure, with local preferences, rather than patient factors, guiding care.

5. Practice of percutaneous tracheostomy

All of the reported methods for percutaneous tracheostomy are based on the Seldinger technique, which allows access to hollow anatomic structures after minimal dissection[55]. Subsequently, dilation up to the degree required for the positioning of the tracheal cannula is necessary, either with a single- or multiple-dilator technique.

a. Preparations

The preparations involve bedside procedures carried out in the ICU. Nasogastric feeding is stopped at least two hours before the planned time of the procedure, and the stomach contents are emptied just before the actual procedure to prevent aspiration into the airway. All patients are ventilated with pressure-controlled ventilation with a FiO_2 of 1.0. Adequate analgesia, sedation and muscle relaxation are ensured. During the procedure, monitoring minimally involves pulse oxymetry, electrocardiography and capnography. The patient's head is positioned in retroflexion with a transverse pillow under the shoulder blades, if permitted. The tube is withdrawn under direct vision, employing a laryngoscope, and so that the inflated cuff is placed in between the vocal cords (see Section 6. Airway control during percutaneous tracheostomy). Simultaneously, the operation site is cleaned with chlorhexidine in 80% alcohol and draped. The landmark structures such as the thyroid notch, cricoid cartilage, and tracheal rings are palpated to define the proper location for the intended tracheostomy placement. It is prudent to check the intended puncture site for large vessels as these may sometimes cause profuse haemorrhaging[56]. Some authors[57-59] even advocate ultrasound to rule out the presence of large blood vessels in the operative field.

b. Procedure

In all percutaneous procedures, we prefer local infiltration with lidocaine 1% with epinephrine 1:100,000, for anaesthesia and haemostasis of the skin and sub-cutaneous tissues. Subsequently, a 2 cm transverse incision is made in the skin and subcutaneous tissues. Some blunt dissection, vertically down to the pretracheal fascia, may be done, to more easily palpate and identify the tracheal cartilages with the tip of the finger[60]. The trachea is punctured with a 14 French cannulated needle attached to a saline filled syringe for continuous suction, aiming for the interspace between the first and second or second and third tracheal rings, although different studies have shown that accurate placement is achieved in less than half of the cases[61-63]. Vertical puncture of the trachea may reduce tracheal wall protrusion and thus might lower the incidence of tracheal stenosis. The puncture is guided by the fibrescopic view[16,60,64-66]. It helps confirming the correct position of the puncture, i.e. in the midline of the anterior trachea, and ensures that the posterior wall is not injured. This is the most crucial step in percutaneous tracheostomy. In addition, fibrescopy allows transillumination of the trachea, which may facilitate the correct identification of the intended puncture site. It should be kept in mind that continuous fibrescopy during percutaneous tracheostomy may contribute to early hypoventilation, hypercarbia, and respiratory acidosis[67,68]. Therefore, if possible, fibrescopic time and suctioning during fibrescopy should be minimised during the procedure, in particular in patients after neurotrauma with the possibility of increasing intracranial pressure. After threading the guide wire and proper dilation, the cannula can be inserted. It is important to actively deflate and lubricate the cannula before introducing it into the trachea.

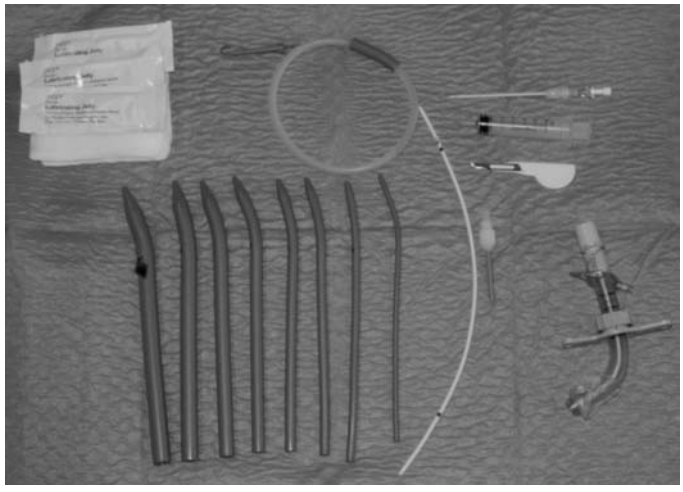
c. Techniques (1-7)

1. Multiple dilator technique: progressive dilational tracheostomy (PDT, Figure 2 and Table 1).

In 1985 Ciaglia et al. were the first to describe percutaneous tracheostomy using a Seldinger technique and thereby avoiding tracheal incision[69]. Over a guide wire, a small introducing catheter is advanced over the guide wire to dilate the initial access site into the trachea. The dilator is then removed while maintaining the guide wire in position and a guiding catheter is advanced over the guide wire up to its skin level

mark. Serial tapered Teflon dilators, from 18 to 38 French, are inserted over a guide wire and its covering guiding catheter for subsequent serial dilation, and followed ultimately by the tracheostomy cannula. Sometimes considerable force is needed to pass the serial dilators, as the edge of the cannula may hook on one of the tracheal cartilages. A lateral insertion of the tip of the cannula may solve this problem[70].

Figure 2. Progressive dilational tracheostomy.



2. *Single dilator technique: Rapitrac™.*

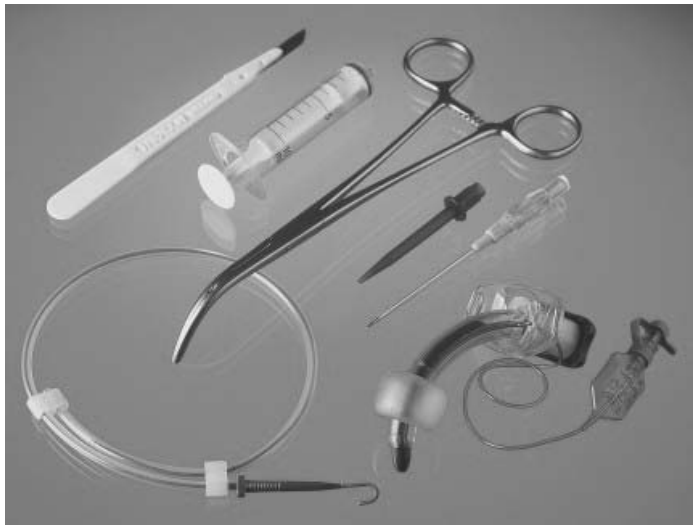
The Rapitrac™ was developed in 1989[71]. It has a sharp instrument tip which is advanced forcibly over a wire into the airway. The disadvantages are the risk of damaging the posterior tracheal wall in thin-necked patients and the inability to penetrate the airway at all in thick-necked patients[64]. Indeed, the use of this device resulted in severe peri-operative complications such as pneumothorax, tracheal stenosis, peritracheal insertion or inability to introduce the cannula[72]. Because the cannula needed to be inserted in between the jaws of the forceps, the insertion was sometimes very cumbersome[44,71-75]. The technique is now obsolete.

3. *Single dilator technique: guide wire dilating forceps*

(GWDF, Figure 3 and Table 2). Chapter 4 b of this thesis.

The GWDF technique was developed by Griggs et al. in 1990[76]. After threading the guide wire, a small dilator is used to predilate the puncture canal. The dilating forceps has a curved point to prevent damage to the posterior tracheal wall and is advanced over the guide wire until resistance is felt. Then the forceps is opened with both hands, to dilate the pretracheal tissues. The forceps is retracted and then readvanced over the guide wire, until it is inside the tracheal lumen. The handles of the forceps are raised to align the jaws in the long axis of the trachea. One-step dilation of the anterior wall of the trachea is achieved using two-handed opening of the forceps. The force required for therapeutic tracheal dilation is usually less than that required for dilation of the pretracheal tissues[77], so the first dilation gives an indication of the force needed for the second dilation. After removal of the forceps, the tracheostomy tube with its specially designed obturator is advanced over the guide wire into the trachea. Finally, the obturator and guide wire are removed.

Figure 2. Guide wire dilating forceps.

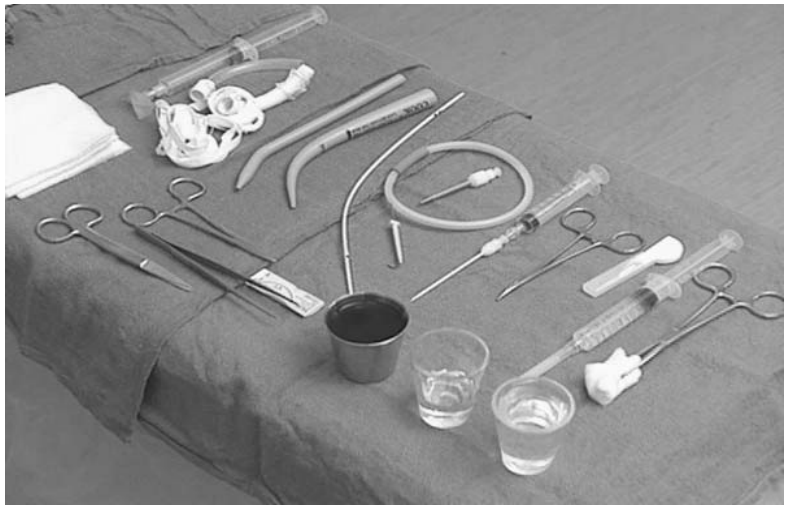


4. Single dilator technique: conic dilational tracheostomy

(CDT, Figure 4 and Table 3). Chapter 4 c of this thesis.

In 1999 the Blue Rhino™ technique became available. It is advisable to use a curved Crile's forceps (Figure 4) for blunt dissection of the cervical fascia anterior to the trachea, perpendicular to the neck[60,78], particularly in cases of unclear anatomy. By using blunt dissection, vessels are usually pushed aside and are not transected. Subsequently, the trachea is punctured with a 17G introducer needle below the cricoid cartilage. A guide wire is inserted and a small dilator is used to predilate the puncture canal. Subsequently, only one 38 French dilator with hydrophilic coating, the Blue Rhino™ dilator, is mounted on a guiding catheter and advanced into the trachea until the 38 French mark on the Blue Rhino™ is detected with the fibrescope. The dilator should be left in place for about half a minute; a tracheostomy cannula is fitted over the 28 French loading dilator and advanced into position.

Figure 4. Conic dilational tracheostomy (Blue Rhino™).



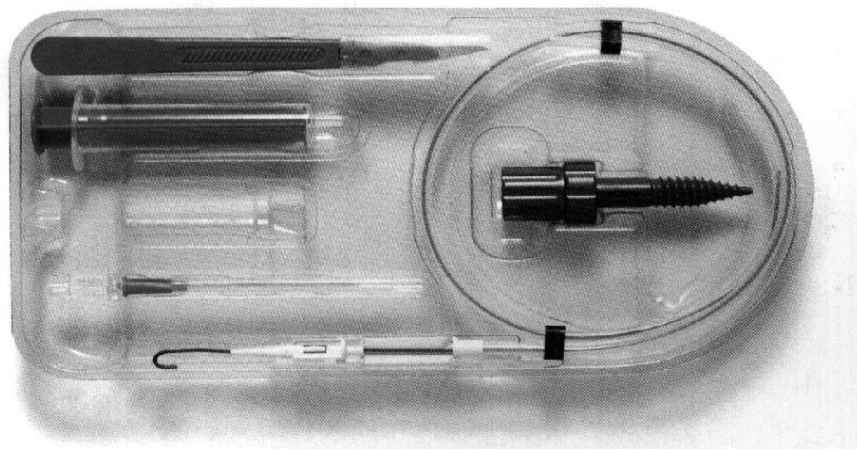
5. Single dilator technique: PercuTwist™

(Figure 5). Chapter 4 e of this thesis.

PercuTwist™ is also a one-step dilation technique. It was reported for the first time by Frova and Quintel in 2002 [79]. It consist mainly of a screw-like dilating device that lifts the anterior tracheal wall during dilation, thus keeping the tracheal lumen open and

enabling an unrestricted fibrescopic view of the dilation site at any given time. After lubricating the hydrophilically coated PercuTwist™ screw in water for several seconds, it is introduced over the guide wire and screwed into the trachea under constant fibrescopic control. The screw is withdrawn and the appropriately sized tracheostomy cannula is introduced into the trachea. Although the results of the first series of 50operations performed by the inventor of the technique were promising[79], follow-up studies reported difficulties in introducing the cannula and posterior wall injury[80,81]. We have decided to abandon its use[82].

Figure 5. PercuTwist™.



6. Fantoni translaryngeal tracheostomy.

The Fantoni translaryngeal tracheostomy will not be discussed here as it is very different from the other percutaneous tracheostomy techniques[83], and also hardly used in the Netherlands[24].

7. Minitracheotomy (Figure 1).

Minitracheotomy was introduced by Matthews and Hopkinson in 1984 [84]. A small bore PVC tube is placed in the trachea via a small transverse incision made in the cricothyroid membrane. Later, the technique was improved by using the Seldinger

technique[85]. The procedure is easy to perform and plays a valuable role in the treatment of sputum retention, even prophylactically in high-risk patients[86]. Little or no sedation is required except for local anaesthesia. It preserves glottic integrity and therefore speech. In some cases, especially in combination with continuous positive pressure ventilation (CPAP) administered by face mask, it may prevent formal intubation/ventilation (Chapter 4 a[87]). However, it is unsuitable for emergency cricothyrotomy (Chapter 6). Although in general, minitracheotomy is an easy procedure, difficulties at insertion were encountered in more than half of cases in an observational study[88]. It must be said, however, that the Seldinger technique was not used in this study. There have been several case reports of complications using this device, including profuse haemorrhage[89-91], tracheal obstruction caused by granuloma formation[92], and oesophageal[93] and pleural[94] misplacements. Therefore, the same precautions as with percutaneous tracheostomy should be taken when introducing a minitracheostomy (see Section 5.a. Preparations).

6. Airway control during percutaneous tracheostomy

Airway control during percutaneous tracheostomy has several pitfalls such as the risk of accidental extubation, endotracheal tube cuff rupture, impalement of the endotracheal tube[95-97], or damage to the fibrescope. There are several ways to control the airway (a.-e.).

a. Tube withdrawal

Our preferred method is to withdraw the endotracheal tube under direct laryngoscopic vision prior to skin preparation and sterile draping, and so that the cuff is placed in between or just below the vocal cords. Care must be taken to avoid unplanned extubation, so the tube should be held firmly by an assistant. Because the position of the head (i.e. with the neck extended) is unfavourable for emergency re-intubation, the role of the anaesthesiologist for airway control is of the utmost importance[17]. It is also possible to withdraw the tube into the pharynx and, following cuff inflation, leaving only its tip into the laryngeal opening, so the tracheal tube cuff acts as a laryngeal inlet obturator. Although in theory this predisposes to aspiration, this was not found to be the case in clinical studies[98,99].

b. Fibrescopic guidance

A fibrescope may be introduced through the endotracheal tube until it passes just beyond the end of the tracheal tube and is then angled maximally in the anterior direction. The room lights are dimmed, the cuff is deflated and the tube and fibrescope are withdrawn simultaneously until the point of maximum transillumination is at the intended puncture site[100].

c. Tube advancement

The tube is advanced distally[101], preferably after replacement with a size 5 to 6 tracheal or microlaryngeal tube[102,103]. During initial tracheal puncture, the cuff needs to be deflated. To rule out transfixation of the tube, it needs to be gently moved within the larynx. There should be no movement of the introducer needle. However, there is a danger of endobronchial tube migration. Moreover, fibrescopic guidance during this procedure is not feasible[104].

d. Tube replacement

It is also possible to replace the endotracheal tube by a laryngeal mask airway[105-108], an intubating laryngeal mask[109], a Combitube™[110],or an Airway Management Device[111]. Furthermore, it is possible to introduce a high frequency jet ventilation catheter through the endotracheal tube and then withdraw the tube into the oro-pharynx[112]. However, all these methods are prone to aspiration of gastric contents. Intensive care patients often require high inflation pressures, have impaired gastric emptying and have oropharyngeal and perilaryngeal oedema secondary to prolonged translaryngeal intubation, making emergency re-intubation hazardous[100,102].

e. Low approach

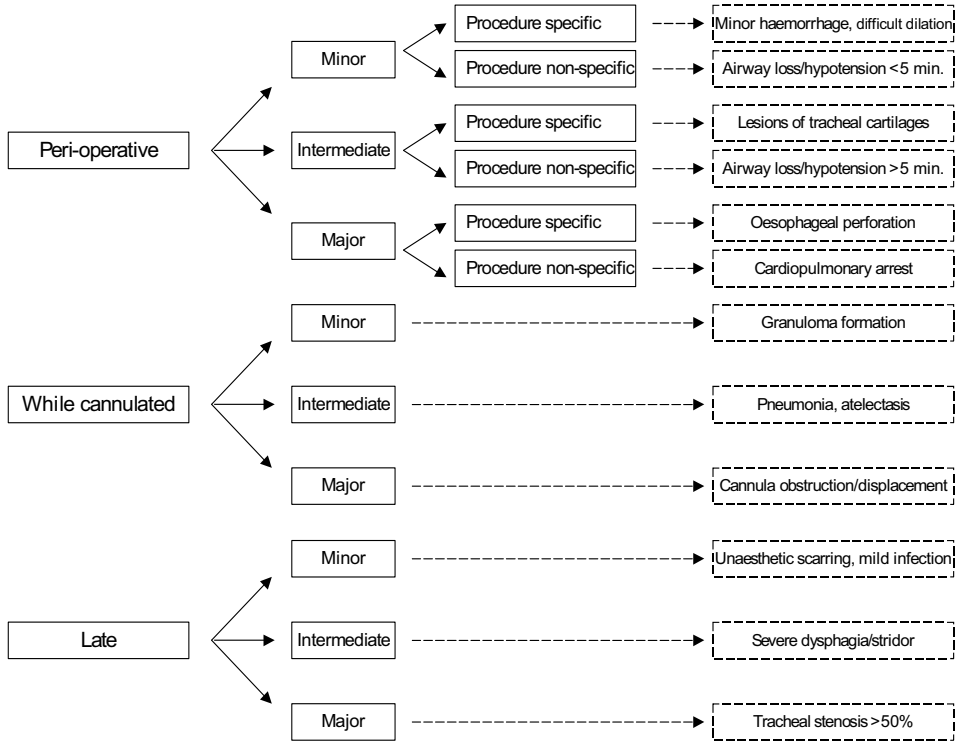
Finally, a low approach by making the incision in the suprasternal notch is presented as a way of obviating fiberscopy[78]. However, a tracheostomy sited below the third tracheal ring carries an increased risk of potential trauma to the thyroid isthmus and of tracheo-innominate artery fistula formation[6], and should therefore be avoided.

Probably the best way to deal with any complications during the procedure is to have a physician with experience in airway control available during percutaneous tracheostomy.

7. Complications of percutaneous tracheostomy

In 1992, a prospective study on percutaneous tracheostomy concluded that '(it) is a dangerous procedure with potential for catastrophic complications'[113]. In this study, however, a Shiley kit was used in the same way as the PDT technique, leading to a number of subtle differences which significantly diminished safety[114], such as a narrower guide wire (which could bend more easily and allowed kinking), absence of a guiding catheter, and no fibrescopic surveillance. Since then, the number of studies published in this field has been increasing each year. Unfortunately, these studies are difficult to compare, because complication rates vary in different series depending on definition and methods of detection. Additionally, a learning curve exists for any of the techniques used in percutaneous tracheostomy[64,113,115-117]. We have tried to make a sound classification of tracheostomy complications (Figure 6), based on Dulguerov et al.[118] and van Heurn et al.[119]

Figure 6. Complications of percutaneous tracheostomy.



'Peri-operative complications' are procedure-related complications occurring within 24 h of the procedure. 'Post-operative complications' are divided into 'complications while cannulated' and 'late complications'. 'Complications while cannulated' are complications occurring after 24 hours until removal of the tracheostomy tube. 'Late complications' occur after removal of the tracheostomy tube. The complications are further subdivided into 'major', 'intermediate', and 'minor' groupings. Because some peri-operative complications are obviously unrelated to the percutaneous technique used (e.g. airway loss, hypotension, impalement of the endotracheal tube, etc.), a further subdivision in 'procedure-specific' and 'procedure-non-specific' may be of value, in particular when comparing two different percutaneous techniques.

'Major complications' are defined as potentially life threatening, requiring immediate surgical or medical intervention. These are, for the most part, objectively defined (death; cardiopulmonary arrest; intraoperative haemorrhage requiring blood transfusion; intratracheal haemorrhage>20 ml; large, complete posterior tracheal wall tear[120]; oesophageal perforation; pneumothorax with drainage; pneumomediastinum; massive subcutaneous emphysema (Chapter 5); mediastinitis; sepsis; cannula obstruction[121] and/or displacement; and tracheal stenosis>50%). Tracheal stenosis<50% usually does not cause clinical symptoms[7,28,122]. Major complications in percutaneous tracheostomy occur in about 3% (0-14%, Tables 1-3) of cases.

'Intermediate complications', when recognised and treated appropriately, should not result in serious morbidity. These include intraoperative haemorrhage>100 ml not requiring blood transfusion; intraoperative hypotension (systolic blood pressure<90 mmHg) for more than five minutes; intraoperative desaturation (SaO2<90%) for more than five minutes; minor tears of the posterior tracheal wall; cannula misplacement; switch from a percutaneous procedure to a surgical technique; pneumothorax without drainage; aspiration pneumonia; atelectasis; lesions of the tracheal cartilages; and late problems such as severe dysphagia or hoarseness. Although the definition of most intermediate complications is precise and objective, the complications may be overlooked in both chart reviews and prospective studies. Intermediate complications in percutaneous tracheostomy occur in about 3% of cases (0-26%, Tables 1-3).

Table 1. Complications of progressive dilational tracheostomy (PDT) in observational studies.

Authors	Peri-operative and while cannulated							Late						
	n	major	(%)	interm.	(%)	minor	(%)	*n*	major	(%)	interm.	(%)	minor	(%)
Hazard et al.[116](1988)	55	3	(5.5)	0	(0)	3	(5.5)	14	0	(0)	0	(0)	0	(0)
Marelli et al.[16](1990)	61	3(†1)	(4.9)	0	(0)	5	(8.2)	NR	-		-		-	
Bodenham et al.[123](1991)	20	1	(5.0)	0	(0)	1	(5.0)	NR	-		-		-	
Ciaglia et al.[124](1992)	165	0	(0)	5	(3.0)	12	(7.3)	52	0	(0)	0	(0)	2	(3.8)
Leinhardt et al.[73](1992)	20	0	(0)	0	(0)	4	(20.0)	NR	-		-		-	
Friedman et al.[30](1993)	100	4(†1)	(4.0)	2	(2)	13	(13.0)	15	1	(6.7)	0	(0)	4	(26.7)
Winkler et al.[125](1994)	71	0	(0)	0	(0)	4	(5.6)	53	0	(0)	0	(0)	4	(7.5)
Gaukroger et al.[126](1994)	50	2	(4.0)	3	(6.0)	0	(0)	NR	-		-		-	
Gillman et al.[127](1996)	37	0	(0)	0	(0)	3	(8.1)	21	0	(0)	0	(0)	0	(0)
van Heurn et al.[119,128,129](1996)	150	5(†1)	(3.3)	2	(1.3)	13	(8.7)	66	1	(1.5)	14	(21.2)	15	(22.7)
Holdgaard et al.[130](1996)	15	0	(0)	0	(0)	6	(40.0)	NR	-		-		-	
Cobean et al.[131](1996)	65	2(†1)	(3.1)	5	(7.7)	7	(10.8)	28	2	(7.1)	2	(7.1)	4	(14.3)
Marx et al.[60](1996)	254	6(†1)	(2.4)	8	(3.1)	8	(3.1)	NR	-		-		-	
Carillo et al.[132](1997)	35	0	(0)	2	(5.7)	3	(8.6)	NR	-		-		-	
Law et al.[122](1997)	NR	-		-		-		41	0	(0)	0	(0)	1	(2.4)
Petros et al.[133](1997)	137	2	(1.5)	3	(2.2)	17	(12.4)	18	1	(5.6)	0	(0)	2	(11.1)
Berrouschot et al.[65](1997)	76	6(†1)	(7.9)	0	(0)	0	(0)	NR	-		-		-	
Heuer et al.[134](1998)	195	3	(1.5)	0	(0)	10	(5.1)	132	1	(0.8)	0	(0)	3	(2.3)

Table 1. (continued)

	n	major	(%)	interm.	(%)	minor	(%)	*n*	major	(%)	interm.	(%)	minor	(%)
Walz et al.[28](1998)	326	10(†2)	(3.1)	5	(1.5)	17	(5.2)	106	1	(0.9)	0	(0)	17	(16.0)
Trottier et al.[135](1999)	24	3	(12.5)	1	(4.2)	3	(12.5)	NR	-		-		-	
Atweh et al.[78](1999)	100	0	(0)	0	(0)	6	(6.0)	NR	-		-		-	
Vigliaroli et al.[136](1999)	304	10	(3.3)	4	(1.3)	5	(1.6)	NR	-		-		-	
Kearny et al.[26,137,138](2000)	827	26(†5)	(3.1)	0	(0)	66	(8.0)	548	9	(1.6)	0	(0)	17	(3.1)
Norwood et al.[139,140](2000)	422	7(†1)	(1.7)	3	(0.7)	8	(1.9)	100	3	(3.0)	10	(10.0)	9	(9.0)
Velmahos et al.[101](2000)	100	4	(4.0)	0	(0)	10	(10.0)	35	0	(0)	0	(0)	5	(14.3)
Massick et al.[115](2000)	100	14	(14.0)	11	(11.0)	26	(26.0)	58	6	(10.3)	0	(0)	3	(5.2)
Mittendorf et al.[141](2002)	71	0	(0)	0	(0)	5	(7.0)	45	0	(0)	0	(0)	2	(4.4)
Beiderlinden et al.[142](2002)	136	9	(6.6)	36	(26.4)	73	(53.7)	NR	-		-		-	
Cumulative	4066	122(†14)	(3.0)(†0.3)	92	(2.3)	335	(8.2)	1311	25	(1.9)	26	(2.0)	88	(6.7)

NR: Not Reported

† : procedure-related death

Table 2. Complications of the GWDF technique in observational studies.

Authors	Peri-operative and while cannulated							Late						
	n	major	(%)	interm.	(%)	minor	(%)	*n*	major	(%)	interm.	(%)	minor	(%)
Griggs et al.[76](1990)	75	0	(0)	0	(0)	1	(1.3)	NR	-		-		-	
Caldicott et al.[143](1995)	20	0	(0)	0	(0)	1	(5.0)	NR	-		-		-	
Wirds et al.[144](1997)	33	1	(3.0)	1	(3.0)	5	(15.2)	NR	-		-		-	
Leonard et al.[145,146](1999)	NR	-		-		-		39	1	(2.6)	13	(33.3)	35	(89.7)
Escarment et al.[29](2000)	162	8(†2)	(4.9)	5	(3.1)	94	(58.0)	73	3	(4.1)	2	(2.7)	7	(9.6)
Fikkers et al.[147,148](2002)	171	5	(2.9)	10	(5.8)	54	(31.6)	106	1	(0.9)	0	(0)	23	(21.7)
Cumulative	461	14(†2)	(3.0)(†0,4)	16	(3.5)	155	(33.6)	218	5	(2.3)	15	(6.9)	65	(29.8)

NR: Not Reported

† : procedure-related death

Table 3. Peri-operative complications of the conic dilational technique (CDT).

Authors	Peri-operative and while cannulated							Late						
	n	major	(%)	interm.	(%)	minor	(%)	*n*	major	(%)	interm.	(%)	minor	(%)
Fikkers et al.[149](2002)	100	5	(5.0)	4	(4.0)	43	(43.0)	64	1	(1.6)	0	(0)	13	(20.3)
Bewsher et al.[150](2001)	36	1	(2.8)	1	(2.8)	13	(2.8)	NR	-		-		-	
Kost et al.[151](2001)	150	2	(1.3)	1	(0.7)	8	(5.3)	20	0	(0)	0	(0)	0	(0)
Cumulative	286	8	(2.8)	6	(2.1)	64	(22.4)	84	1	(1.2)	0	(0)	13	(15.5)

Finally, 'minor complications' are somewhat subjective, less serious, easier to correct, and rely on the diligence with which they are sought and reported, since they are rarely presented in medical records. These consist of loss of airway with prompt re-intubation; damage to the endotracheal tube or fibrescope; passage of the introducer needle through the Murphy's eye of the translaryngeal tube[95-97]; haemorrhage<100 ml or some intratracheal blood clots; false passage of the cannula (if corrected promptly); difficulty with cannula placement; minor subcutaneous emphysema; infections such as cellulitis and tracheitis not requiring antibiotic therapy; and late problems, such as granuloma formation around the tracheostoma; tracheal stenosis<50%; delayed closure of tracheostomy tract; keloids; and unaesthetic scarring. The incidence of minor complications is around 20% (Tables 1-3), but there is a considerable study-to-study variability of reported complication incidence (1-58%).

Ideally, patients should be followed up either until death or until the trachea has been allowed to heal for several months after removal of the tracheostomy tube. Such an extensive duration was studied in the minority of publications. Unless the events are recorded as critical incidents or as part of an ongoing audit, underreporting of acute complications will occur[152]. Moreover, many complications are not recognised clinically, e.g. tracheal ring fracture is often found only post-mortem[153], although it is reported relatively more frequently after use of the conic dilational technique[142,154,155]. In general, there is a low rate of infective complications, because of the small incision[26], and the tight fit of the cannula[156,157], although cases of major cellulitis have been described[158].

The procedure-related mortality should be defined as mortality associated with the procedure. This may involve the peri-operative period as well as during cannulation. This mortality rate is less then 0.5% (Table 4). Catastrophic haemorrhage is rare, usually delayed and commonly the result of tracheo-arterial or -venous fistulae[56], although some case reports mention early haemorrhage related to previous neck surgery[58,159]. Due to the low mortality rate of the procedure itself and the high mortality rate of the targeted patient population, a mortality analysis to compare surgical and percutaneous tracheostomies is difficult to perform.

Table 4. Mortality due to percutaneous tracheostomy (from Tables 1-3).

Authors	Arrhythmia	Massive bleeding	Tracheal wall laceration	Bronchospasm MOF	Tube dislodgement/ obstruction
Marelli et al.[16](1990)	1	-	-	-	-
Friedman et al.[30](1993)	-	1	-	-	-
van Heurn et al.[119](1996)	-	1	-	-	-
Cobean et al.[131](1996)	-	-	-	-	1
Marx et al.[60](1996)	-	-	-	-	1
Berrouschot et al.[65](1997)	-	-	1	-	-
Walz et al.[28](1998)	1	-	-	-	1
Kearny et al.[137](2000)	-	-	-	2	3
Norwood et al.[139](2000)	-	-	1	-	-
Escarment et al.[29](2000)	-	-	-	-	2
Cumulative	2	2	2	2	8

The analysis of late complications is extremely difficult, because an airway injury caused by translaryngeal intubation is an important confounder. This is a challenge for future research (see Section 11. Future perspectives).

Treatment of complications is largely symptomatic. For some specific complications, specific treatments are available, for example, large posterior wall tears may be treated with a covered expandable metallic stent[160].

In conclusion, the complication rate of percutaneous tracheostomy varies enormously, depending on type of study and definitions used. The complication rate of surgical tracheostomy also varies enormously (6-50%), according to different literature reviews[11,13,161]. It is very important to standardise the definitions of complications in order to make useful comparisons possible. Because minitracheotomy is different from percutaneous tracheostomy in several respects (location of puncture, size of cannula), its complications are discussed separately.

8. Comparison of different tracheostomy procedures

a. Percutaneous tracheostomy compared to the surgical technique (Table 5).

Studies of surgical and percutaneous tracheostomies are difficult to compare because of different design, definitions and follow-up (see Section 7. Complications). Since 1985, nearly 300 case series have been published comparing surgical and percutaneous techniques[162]. A meta-analysis published by Dulguerov in 1999 showed no advantages for the percutaneous tracheostomy[118]. On the contrary, it showed more peri-operative complications in the percutaneous group, including deaths. However, both prospective and observational studies had been included, while different (and even obsolete) percutaneous techniques were being compared, so the meta-analysis was heavily criticised[163-166]. Three other recent meta-analyses of five prospective, randomised trials comparing percutaneous and surgical tracheostomies in ICU patients[167-169] found that peri- and post-operative complications were far less frequent with the percutaneous techniques. However, these meta-analyses on prospective, randomised trials have also been criticised, because the studies included were too heterogeneous to allow pooling of their data ('a meta-analysis, but not the final analysis'[170]). Since then, four more prospective randomised studies have been published, two in favour of surgical tracheostomy (Massick[171] and Dulguerov[172], who also published a meta-analysis in favour of surgical tracheostomy[118]), and two in favour of percutaneous tracheostomy (Heikkinen[17] and Freeman[20], who also published a meta-analysis in favour of percutaneous tracheostomy[167]). Table 5 clearly shows the large variation in reported incidences of complications.

Table 5. Summary of clinical trials comparing surgical and percutaneous techniques.

Authors			Peri-operative complications					
	techniques	*n*	major	(%)	interm.	(%)	minor	(%)
Observational studies:								
Griggs et al.[173](1991)	ST	74	5	(6.8)	0	(0)	9	(12.2)
	GWDF	153	2	(1.3)	0	(0)	4	(2.6)
Leinhardt et al.[73](1992)	ST	16	2	(12.5)	0	(0)	2	(12.5)
	PDT	20	0	(0)	0	(0)	3	(15.0)
Graham et al.[174](1996)	ST	29	3	(10.3)	2	(6.9)	12	(41.4)
	PDT	31	4	(12.9)	3	(9.7)	13	(41.9)
Stoeckli et al.[156](1997)	ST	36	3	(8.3)	0	(0)	9	(25.0)
	PDT	47	3	(6.4)	0	(0)	3	(6.4)
Khalili et al.[175](2002)	ST	252	0	(0)	5	(2.0)	2	(.8)
	PDT	94	0	(0)	2	(2.1)	0	(0)
Prospectively Randomised (PR):								
Hazard et al.[176](1991) PR	ST	24	1	(4.2)	4	(16.7)	8	(33.3)
	PDT	22	2	(9.1)	0	(0)	1	(4.5)
Crofts et al.[177](1995) PR	ST	28	1	(3.6)	0	(0)	9	(32.1)
	PDT	25	0	(0)	0	(0)	5	(20)
Friedman et al.[178](1996) PR	ST	27	5(†3)	(18.5)	0	(0)	18	(66.7)
	PDT	26	2	(7.7)	2	(7.7)	8	(30.8)
Holdgaard et al.[157](1998) PR	ST	30	4	(13.3)	10	(33.3)	44	(100)
	PDT	30	2	(6.7)	1	(3.3)	24	(80.0)
Porter et al.[179](1999) PR	ST	12	0	(0)	0	(0)	1	(8.3)
	PDT	12	1(†1)	(8.3)	0	(0)	3	(25.0)
Gysin et al.[172](1999) PR	ST	35	0	(0)	2	(5.7)	10	(28.6)
	PDT	35	1	(2.9)	6	(17.1)	21	(60.0)
Heikkinen et al.[17](2000) PR	ST	26	0	(0)	3	(11.5)	3	(11.5)
	GWDF	30	0	(0)	1	(3.3)	1	(3.3)
Massick et al.[171](2001) PR	ST	50	0	(0)	3	(6.0)	0	(0)
	PDT	50	5(†1)	(10.0)	6	(12.0)	0	(0)
Freeman et al.[20](2001) PR	ST	39	2(†1)	(5.1)	0	(0)	0	(0)
	PDT	39	0	(0)	4	(10.3)	0	(0)

† : procedure-related death

Table 6. Incidence of peri-operative complications reported in trials shown in Table 5.

Technique	*n*	major	(%)	interm.	(%)	minor	(%)
ST	678	26	3.8%	28	4.1%	127	18.7%
PDT	431	20	4.6%	24	5.6%	81	18.8%
GWDF	183	2	1.1%	1	.5%	5	2.7%
Total	1292	48	3.7%	53	4.1%	213	16.5%

Most studies conclude that percutaneous tracheostomy is a safe alternative to surgical tracheostomy, with definitely less infectious complications. Unfortunately, there are still insufficient data to establish clear superiority of either technique.

b. Percutaneous tracheostomy compared with other percutaneous techniques (Table 7).

The first studies comparing two techniques in this field were those on the progressive dilational technique and the GWDF technique[146,180-183]. The first three (retrospective) studies did not show any difference between the two techniques; the following two studies, which were adequately randomised, showed significantly more complications in the GWDF group, both major (bleeding requiring blood transfusion[182]) and minor (difficult cannula insertion[183]).

Only a few studies compared the progressive dilational technique with the conic dilational technique[155,184,185]. All studies conclude that the conic dilational technique is more rapidly and easily performed with equivalent complications. The use of a single tapered dilator markedly reduces the number of times the airway is manipulated during the procedure and also reduces the risk of loss of the airway or injury to the posterior tracheal wall.

Two studies compare the GWDF technique with the conic dilational technique[186,187]. They both found equivalent complications. A major concern with the conic dilational tracheostomy is a significant amount of tracheal cartilage fractures[142,154,155,186], although there were no clinical consequences. Presumably this is because of the rapid one-step

dilation in the conic dilational tracheostomy in contrast to the stepwise dilation in the progressive dilational tracheostomy. Although it is said that tracheal cartilage fractures after percutaneous tracheostomy rarely result in tracheal strictures or stenosis of clinical relevance after decannulation[19], this subject awaits further studies.

Table 7. Summary of clinical trials comparing two percutaneous techniques.

Authors		Peri-operative complications						
	techniques	*n*	major	(%)	interm.	(%)	minor	(%)
van Heerden et al.[146](1996)	PDT	29	0	(0)	0	(0)	10	(34.5)
	GWDF	25	0	(0)	1	(4.0)	6	(24.0)
Ambesh et al.[180](1998)	PDT	40	0	(0)	0	(0)	10	(25.0)
	GWDF	40	1	(2.5)	0	(0)	10	(25.0)
Añon et al.[181](2000)	PDT	25	0	(0)	2	(8.0)	5	(20.0)
	GWDF	38	0	(0)	3	(7.9)	8	(21.1)
Nates et al.[182](2000) PR	PDT	50	1	(2.0)	0	(0)	5	(10.0)
	GWDF	50	7	(14.0)	2	(4.0)	6	(12.0)
van Heurn et al.[183](2000) PR	PDT	63	2	(3.2)	0	(0)	5	(7.9)
	GWDF	64	3	(4.7)	4	(6.3)	13	(20.3)
Cothren et al.[185](2002)	PDT	49	0	(0)	0	(0)	1	(2.0)
	CDT	44	1	(2.3)	1	(2.3)	0	(0)
Byhahn et al.[155](2000) PR	PDT	25	1	(4.0)	4	(16.0)	2	(8.0)
	CDT	25	0	(0)	9	(36.0)	2	(4.0)
Johnson et al.[184](2001) PR	PDT	25	0	(0)	0	(0)	14	(56.0)
	CDT	25	0	(0)	0	(0)	12	(48.0)
Fikkers et al.[187](2004)	GWDF	171	11	(6.4)	10	(5.8)	51	(29.8)
	CDT	171	13(†1)	(7.6)	5	(4.3)	97	(56.7)
Ambesh et al.[186](2002) PR	GWDF	30	1(†1)	(3.3)	5	(16.7)	17	(56.7)
	CDT	30	1	(3.3)	1	(3.3)	17	(56.7)
Byhahn et al. [81](2002) PR	CDT	35	0	(0)	0	(0)	7	(20.0)
	PercuTwist	35	2	(5.7)	6	(17.1)	4	(11.4)

PR: Prospectively Randomised

Table 8. Incidence of peri-operative complications reported in trials shown in Table 7.

Technique	*n*	major	(%)	interm.	(%)	minor	(%)
PDT	306	3	1.0%	3	1.0%	53	17.3%
GWDF	418	23	5.5%	25	6.0%	111	26.6%
CDT	330	15	4.5%	9	2.7%	133	40.3%
PercuTwist	35	2	5.7%	6	17.1%	4	11.4%
Total	1089	43	3.9%	43	3.9%	301	27.6%

9. Special subgroups

Some subgroups were studied with a special focus on the use of percutaneous tracheostomy. These will be discussed below.

a. Obesitas. A number of case reports[188-190] and one series involving 13 patients[191] were published describing successful accomplishment of percutaneous tracheostomy in morbidly obese patients. At the Annual Meeting of the American Society of Anesthesiologists, a case-control study was presented[192] of 73 morbidly obese patients (from a group of 474 patients). In the obese patients group, a more than tenfold increase of major complications was found compared to the control group. In obese patients, the risks and benefits of percutaneous tracheostomy should therefore be carefully balanced.

b. Poststernotomy. Surgical tracheostomies are frequently colonised and infected and therefore constitute a risk factor for mediastinitis after cardiac operations[193]. In 1973, cricothyrotomy was advocated to prevent median sternotomy infections[194]. More recently it was proven that percutaneous tracheostomy is safe in this respect[134,195] and the procedure can be advised in early poststernotomy patients who are expected to be ventilated for a prolonged period of time[196].

c. Trauma with presumed neck injury. Percutaneous tracheostomy can be safely performed without cervical spine clearance and neck extension in trauma patients who require long-term airway management[197]. However, because the procedure is

slightly more complex, physicians with limited percutaneous tracheostomy experience should not perform it.

d. Coagulation abnormalities. Advantages of percutaneous tracheostomy are the tight fit of the tract around the tracheostomy tube, which compresses any small bleeding vessels. Because it involves minimum tissue dissection, it is therefore suitable for patients with high bleeding risk[198]. Although coagulation abnormalities are no longer an absolute contra-indication, correction of haemostasis should be meticulously performed. Some authors[199] believe that the translaryngeal tracheostomy is superior to other percutaneous techniques in patients with coagulopathy.

10. Cannula change/displacement

Patients in the ICU may have a tracheostomy tube without an inner cannula, but patients on the general ward should always have a tracheostomy tube with a removable inner cannula, to facilitate cleaning of the inner lumen and thereby ensure the maintenance of a clear airway. The first tracheostomy tube change is sometimes difficult due to the very small stoma[146]. It is recommended to change such tubes once a month, depending on the manufacturer's guidelines[200]. Tubes without an inner cannula need to be changed more frequently, to ensure a patent airway. It is recommended to change single lumen tubes every 7-10 days. An elective cannula change should be well prepared. The patient should be in the supine position with the neck in hyperextension. Early elective cannula changes should always be performed using an exchange device, like a cut suction catheter. In patients with marginal oxygenation, a Cook airway exchange catheter[28,198] or a well lubricated, plain, uncut, oral or nasal PVC tracheal tube[201] may be used. The tube should be of a diameter that is slightly smaller than the internal diameter of the tracheostomy cannula. In this manner, the airway is secure at all times, so the changeover can be gentle and unhurried, and ventilation (if required) needs only be interrupted during the few seconds that the connector is removed.

Features unique to percutaneous tracheostomy that increase the risk of delayed airway loss include the tight fit of the pretracheal conduit around the cannula, and the lack of a formal stoma creation. Cannula displacement represents a potentially catastrophic complication, particularly in patients with massive oedema who are likely to be difficult

to intubate. One should always be prepared for inadvertent decannulation by using flexible tubing and eventually by suturing the cannula to the skin[142]. Several fatalities in adult patients have occurred because of cannula displacement[28,29,115,171,178,180,186], being the most important cause of mortality of the procedure (Table 4). Should the tracheostomy become dislodged during the first two weeks after insertion, it is highly advisable to orally re-intubate the patient to secure the airway, because a stoma tract has not developed sufficiently to allow safe recannulation as it may collapse after removal of the cannula[60,131,202]. Tube obstruction is a relatively common complication with tracheostomy cannulas, although the better design of newer cannulas seem to reduce its incidence[121]. It can be caused by blood, mucus and sputum, but it can also be secondary to the posterior membranous portion of the trachea and the lateral tracheal wall encroaching on the distal lumen of the cannula. In a recent publication in Chest, this was explained by chronic irritation of the posterior tracheal wall and the acronym TWISTED was suggested (*ie*, Tracheal Wall Injury with intermittent Stoppage of the Tracheostomy and Episodes of Dyspnoea)[203].

11. Future perspectives

Improved methods for early identification of patients who are likely to survive a prolonged course of mechanical ventilation need to be developed, as was done for patients with infratentorial lesions[50]. In this way, it will be possible to more rapidly target these patients for interventions such as tracheostomy, aimed at reducing the prolonged stay on mechanical ventilation[4]. Therefore, it is of great interest to design a prospective randomised trial on early tracheostomy. This was tried by Sugerman et al. in 1997[52], but this trial failed because of numerous problems.

Because many complications (including fatalities!) become manifest long after the patient has left the ICU, a multidisciplinary team approach will improve the care of patients with tracheostomies. Such a dedicated team, comprised of doctors, nurses, speech therapists, and physiotherapists, should work closely together. It is highly desirable that an ICU nurse follows patients with a tracheostomy on the general ward and is available for consultation.

No data support the conclusion that early tracheostomy either decreases or increases the risk of ventilator-associated pneumonia[162]. Among the different strategies to

decrease the incidence of ventilator-associated pneumonia, subglottic drainage has been proven to be effective in patients with translaryngeal intubation[204]. Another ongoing discussion is about the most appropriate method for the late follow-up of percutaneous tracheostomy after decannulation[61]. Many asymptomatic patients may have tracheal stenosis up to 50%[7,28,122]. Therefore, we are currently evaluating follow-up with pulmonary function tests (F/V: flow/volume-curves and FOT: forced oscillation technique[205]) and MRI to diagnose tracheal stenosis[206-208]. The degree of tracheal stenosis will be calculated planimetrically[61]. At the same time, we want to investigate whether the use of a cannula with the possibility of subglottic drainage decreases the incidence of ventilator-associated pneumonia in patients with a percutaneous tracheostomy, compared to the use of a conventional cannula.

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Chapter 8

Summary

This thesis deals with various aspects of percutaneous tracheostomy. The aim of this thesis is to describe the practice of the most frequently used percutaneous tracheostomy techniques, to assess their safety profiles, both short- and long-term, to compare the most frequently used techniques, and to study in detail various serious adverse events.

Chapter 2 gives an overview of the history of tracheostomy. The procedure has always fascinated doctors since antiquity, but until the 19th century it was rarely performed and involved high mortality. Since the diphtheria epidemics in the 19th century, the procedure was performed more often. Chevalier Jackson (1865-1958) described modern surgical tracheostomy in the early 1900s. The neurosurgeon C. Hunter Shelden (1907-2003) devised the first modern percutaneous kit in 1955. With his description of his novel technique using a Seldinger technique in 1985, Pasquale Ciaglia (1912-2000), a thoracic surgeon from New York, popularised percutaneous tracheostomy considerably.

Chapter 3 gives background information on the frequency, timing, technique and follow-up of tracheostomy in intensive care units in the Netherlands. Timing and technique vary widely in Dutch ICUs. The percutaneous technique is the procedure of choice for tracheostomy in most of these units. About one third of the ICUs used fibre-optic control during the procedure. Late follow-up protocols are rarely in use.

Chapter 4 describes the different percutaneous tracheostomy techniques in use in the intensive care unit of the University Medical Centre Nijmegen (minitracheotomy, and the Guide Wire Dilating forceps, Blue Rhino™ and PercuTwist™ techniques) and analyses their complications. CPAP via minitracheotomy is a way to postpone tracheostomy in patients with laryngospasm, in particular in patients with Parkinson's disease. The Guide Wire Dilating forceps technique and the Blue Rhino™ technique appear equally effective. Although the PercuTwist™ technique is theoretically attractive, we think the screwing procedure is too difficult to make it a good alternative to the other percutaneous techniques at present.

Chapter 5 analyses the complications of percutaneous tracheostomy. The importance of using a bronchoscope is highlighted, and the occurrence of pneumothorax and subcutaneous emphysema is explained. The incidence of pneumothorax is about 0.8% and of emphysema about 1.4%. In patients in whom fenestrated cannulas are used, air leakage between the inner and outer cannulas may occur, causing subcutaneous emphysema. Therefore, these cannulas should not be used after percutaneous tracheostomy.

In Chapter 6, two techniques of emergency cricothyrotomy are compared, the QuickTrach™ and the Minitrach™. Whereas the former appeared to be safe and reliable, the latter proved unsuitable for emergency situations.

Finally, Chapter 7 gives a general overview of the indications; contra-indications; the use in emergency situations; timing; techniques; airway control; and complications of percutaneous tracheostomy. The incidence of major complications is about 3% (0-14%). The incidence of intermediate and minor complications is variable and varies much depending on the diligence with which they are sought and reported. Surgical and percutaneous techniques are compared. There are still insufficient data to establish clear superiority of either technique. The procedure-related mortality of percutaneous tracheostomy is less than 0.5%. The most important cause is accidental decannulation with inability to recanulate the trachea.

On the basis of the above-mentioned data, we could not establish that one of the percutaneous tracheostomy techniques is better than the others. Improvement in patient care is required, particularly on the wards, since it is there that morbidity and mortality strike most. Consultative intensive care nurses, checking on patients with a tracheostomy on the general ward, can play an important role in this respect.
In emergency situations, procedures involving the Seldinger technique are not in favour. In these situations, the catheter-over-the-needle procedure appears to be quick, safe and reliable.

Chapter 9

Samenvatting

Een tracheotomie is een ingreep waarbij een opening in de voorzijde van de luchtpijp (trachea) wordt gemaakt. Dit kan geschieden op twee manieren: chirurgisch of percutaan. Bij de laatstgenoemde techniek wordt door de huid (=percutaan) de luchtpijp met een naald aangeprikt, waarna op verschillende manieren een canule in de luchtpijp wordt geschoven.

Hoofdstuk 1 licht de doelstellingen van dit proefschrift toe. De essentie bestaat uit het beschrijven en met elkaar vergelijken van de meest gebruikte percutane tracheotomie-technieken ten aanzien van het optreden van vroege en late complicaties.

Hoofdstuk 2 geeft een historisch overzicht van de tracheotomie. De procedure heeft artsen sinds de oudheid gefascineerd. Gezien de hoge sterfte tijdens of vlak na de procedure werd de techniek tot in de 19e eeuw zelden gebruikt. Sinds de difterie-epidemieën in de 19e eeuw wordt een tracheotomie steeds vaker uitgevoerd. De moderne chirurgische tracheotomie is beschreven door de KNO-arts Chevalier Jackson (1865-1958) in het begin van de twintigste eeuw. De neurochirurg Hunter Shelden (1907-2003) ontwierp de eerste moderne percutane kit in 1955. Rond dezelfde tijd heeft de Zweedse radioloog Sven-Ivar Seldinger (1921-1998) voor het eerst een techniek beschreven waarbij toegang tot een holle ruimte, zoals een bloedvat, werd verkregen met behulp van een naald waar doorheen een flexibele voerdraad werd geschoven. Vervolgens werd de naald over de voerdraad verwijderd en werd een katheter in het vat geschoven. Met betrekking tot de percutane tracheotomie werd van dit principe voor het eerst gebruik gemaakt in 1985 door Pasquale Ciaglia (1912-2000), een thoraxchirurg uit New York. Sindsdien wordt deze techniek steeds frequenter gebruikt.

Hoofdstuk 3 geeft achtergrondinformatie over hoe vaak, op welk moment, met welke technieken en met welke nazorg een tracheotomie op intensive-careafdelingen in Nederland verricht wordt. Het moment van de ingreep en de gebruikte technieken variëren sterk op de verschillende Nederlandse intensive-careafdelingen. Bij de meerderheid van de artsen werkzaam op een intensive care heeft de percutane techniek de voorkeur boven de chirurgische. Op ongeveer eenderde van de intensive-

careafdelingen wordt een zgn. bronchoscoop gebruikt tijdens de procedure. Dit is een flexibele kijker waarmee de luchtpijp kan worden geïnspecteerd tijdens de procedure. Follow-upprotocollen worden zelden gebruikt.

Hoofdstuk 4 beschrijft de verschillende percutane tracheotomietechnieken die gebruikt worden in het Universitair Medisch Centrum St Radboud in Nijmegen: de minitracheotomie, de technieken met spreidende tang, de Blue Rhino™ (een conische dilatator) en de PercuTwist™ (een techniek waarbij gebruik gemaakt wordt van een dilatator met een schroefdraad). Tevens vindt een uitvoerige analyse van de complicaties plaats. In een casus wordt een patiënt beschreven met een ernstige kramp van de stembanden (laryngospasme), geassocieerd met de ziekte van Parkinson. Behandeling vond plaats met continue positieve luchtwegdruk (CPAP), gegeven via een minitracheotomie. Dit bleek een effectieve manier voor de behandeling van dit probleem.
De technieken met spreidende tang en de Blue Rhino™ zijn met elkaar vergeleken en blijken even effectief. Hoewel de PercuTwist™ techniek aantrekkelijk lijkt op theoretische gronden, hebben wij de ervaring dat het schroeven te lastig en te zwaar gaat, zodat het geen alternatief vormt voor de andere technieken.

Hoofdstuk 5 analyseert de complicaties van de percutane tracheotomie. Het belang van het gebruik van de bronchoscoop wordt toegelicht en het ontstaan van een pneumothorax (klaplong) of subcutaan emfyseem (lucht onder de huid) wordt verklaard. Een pneumothorax komt in ongeveer 0,8% van de gevallen voor en emfyseem in ongeveer 1,4% van de gevallen. Indien het wenselijk is om de patiënt te laten spreken, dan kan gebruik worden gemaakt van een zgn. gefenestreerde canule. Hierbij zit er een opening halverwege de canule, waardoor de patiënt kan inademen door de canule en kan uitademen door de stembanden. Indien een dergelijke canule direct wordt ingebracht, kan lucht lekken tussen binnen- en buitencanule, waardoor subcutaan emfyseem kan ontstaan. Daarom moeten dergelijke canules nimmer direct in aansluiting op een percutane tracheotomie gebruikt worden.

In hoofdstuk 6 wordt de toegang tot de luchtweg in acute situaties besproken. Hierbij wordt in het algemeen de cricothyrotomie gebruikt, een toegang tot de luchtweg via het

vlies dat zich bevindt tussen het strottenhoofd (thyroid) en het zegelring-kraakbeen (cricoid). Twee technieken van de spoedcricothyrotomie worden met elkaar vergeleken, de QuickTrach™ en de Minitrach™. De eerstgenoemde techniek, die gebruik maakt van een katheter over de naald, blijkt veilig en betrouwbaar, terwijl de laatstgenoemde techniek, die gebruik maakt van de Seldinger-techniek, minder geschikt blijkt voor spoedsituaties.

Tenslotte geeft hoofdstuk 7 een literatuuroverzicht van de (contra-)indicaties, het gebruik in spoedsituaties, het moment van de ingreep, de technieken, de luchtwegcontrole en de complicaties van percutane tracheotomie. Ernstige complicaties komen ongeveer in 3% (0-14%) van de gevallen voor. De rapportage van matige en geringe complicaties is zeer variabel en is afhankelijk van de ijver waarmee ernaar gezocht wordt. Chirurgische en percutane technieken worden met elkaar vergeleken. Er is nog steeds onvoldoende bewijs om het voordeel van de een of andere techniek definitief aan te tonen. De sterfte gerelateerd aan de percutane tracheotomie is minder dan 0,5%. De meest voorkomende doodsoorzaak is het per ongeluk luxeren van de canule uit de luchtpijp, waarna het niet mogelijk blijkt om deze opnieuw in de luchtpijp te schuiven.

Op basis van deze gegevens hebben wij niet kunnen aantonen dat een van de percutane technieken beter is dan een andere. Wel is het is wenselijk de directe zorg rondom de tracheacanule te verbeteren, in het bijzonder op de gewone verpleegafdeling, aangezien daar de meeste calamiteiten optreden. Een consultatieve intensive-careverpleegkundige die dagelijks langs de patiënten met een tracheostoma loopt, zou hierbij een belangrijke rol kunnen spelen. In de literatuur komen steeds meer aanwijzingen dat een vroege tracheotomie het ontwennen van mechanische beademing kan vergemakkelijken. Echter, deze voordelen zullen altijd moeten worden afgewogen tegen de kans op het optreden van complicaties, zoals in dit proefschrift beschreven.

Dankwoord

Dankwoord

Onderzoek doe je nooit alleen en het schrijven van een proefschrift is allang niet meer het werk van één persoon. Velen zijn dan ook direct of indirect betrokken geweest bij de totstandkoming van dit proefschrift en allen ben ik hoogst erkentelijk. Dit was mij alleen nooit gelukt. Ik wil hier met name graag die mensen bedanken, die een substantiële bijdrage hebben geleverd:

Frank van den Hoogen en Henri Marres, jullie waren het die vanaf het begin in april 2000 een vast vertrouwen hadden in de voltooiing van mijn boekje. Hoewel destijds het klimaat op de afdeling intensive care nog verre van academisch was, hebben jullie gelijk gekregen.
Met de komst van Hans van der Hoeven in 2003 is er veel op onze intensive care veranderd. Hans, ik ken je al vanaf mijn eerste schreden in de kliniek als co-assistent in het St. Claraziekenhuis in 1985. Destijds was ik al onder de indruk van je medische kennis en je didactische vaardigheden, ook toen we samenwerkten in het Rode Kruis Ziekenhuis en later in het Academisch Ziekenhuis Leiden. Ik was dan ook zeer verheugd toen ik vernam dat je besloten had naar Nijmegen te komen. Het is zeker zo dat dankzij jou een en ander in een stroomversnelling is geraakt.
Christian Byhahn, mit dir tausche ich seit dem Jahr 2000 regelmäßig über e-Mail Gedanken aus über meine Forschung. Anfang dieses Jahres konnte ich dich in Frankfurt a.M. besuchen. Ich danke dir für dein Vertrauen, du hast mir uneigennützig deine Ergebnisse zür Verfügung gestellt. Ich wünsche dir viel Erfolg mit deiner Habilitation.
Niels van Heerbeek, jij was mijn eerste “student” en hebt met mij samen de eerste data uitgewerkt. Het verloop van je carrière nadien heb ik met bewondering gevolgd! Inge Briedé, André van Veen, Marieke Staatsen, Sabine Lardenoije en Stijn van Vugt vervulden destijds ook op voortreffelijke wijze hun wetenschappelijke stage en zij hebben een belangrijke bijdrage geleverd aan de totstandkoming van de artikelen.
Verder gaat mijn dank uit naar de overige medeauteurs en mijn collegae van de intensive care, die allen op hun eigen manier een steentje hebben bijgedragen. Met name Jeroen Verwiel stond altijd klaar om een percutane tracheotomie te verrichten. Peter Pickkers was een welkome vraagbaak tijdens de afrondingsfase. Ik ben blij dat je sinds het begin van dit jaar mijn kamergenoot bent geworden. Leo van Rossum, jou wil ik graag bedanken voor je hulp bij het vervaardigen van een solide database.

In de periode dat dit proefschrift tot stand gekomen is, zijn zowel mijn vader als mijn schoonvader overleden. Het zou mooi geweest zijn wanneer ze beiden bij de promotieplechtigheid aanwezig zouden zijn geweest.
Het liefst zou ik ook meer dan twee paranimfen hebben gehad. Helaas kunnen er op 9 september maar twee 'live' naast me staan. Rik, "mijn vriend", jouw promotiegebeuren heb ik van nabij mogen meemaken en heb ik van je adviezen en ervaringen mogen profiteren. Nog prettiger is de leuke tijd die we de laatste jaren met onze gelijk oplopende gezinnen hebben doorgebracht. Akosua, ik ben blij dat je één van mijn paranimfen wilt zijn, samen met Jos, "*for old times sake*".
Dankzij Nel Heikens is het Nederlandse deel volgens de laatste (ondoorgrondelijke) inzichten van de Nederlandse grammatica geschreven. Jeske Bongers en Marc Regenboog, veel dank voor het geduld en uithoudingsvermogen om de laatste versie om te zetten in een voor de drukker hapklare brok.

Hilde, hier geen jammerklachten over "de gemiste tijd met de kinderen en de verwaarlozing van de partner". Sinds ik jou ken, hebben we samen ontzettend veel meegemaakt. Mede door je nuchtere Friese afkomst was de totstandkoming van dit proefschrift geen zware opgave. We gaan zo door, en worden hopelijk samen heel oud!

Nijmegen, april 2004. Bernard Fikkers

Curriculum vitae

Curriculum vitae

Bernard Fikkers werd op 25 oktober 1961 in Groningen geboren en groeide vanaf 1963 op in Den Haag. In 1979 behaalde hij het atheneum-B diploma aan het Aloysius College te Den Haag en in 1987 het artsexamen aan de Erasmus Universiteit Rotterdam. Aansluitend was hij één jaar AGNIO op de afdeling interne geneeskunde in het Rode Kruis Ziekenhuis te Den Haag. In 1988 werd aangevangen met de opleiding anesthesiologie in het Academisch Ziekenhuis Leiden (opleider prof. dr. J. Spierdijk). Registratie als anesthesioloog vond plaats in 1992. Vanaf 1993 was hij fellow in opleiding tot intensivist in het Onze Lieve Vrouwe Gasthuis te Amsterdam (opleider dr. D.F. Zandstra). In 1994 werd het Europese Intensive Care diploma verkregen en vond de registratie tot anesthesioloog-intensivist plaats. Nadien volgde een fellowship in regional anesthesia in de Virginia Mason Clinic in Seattle. Sinds 1 oktober 1995 is hij staflid op de afdelingen Anesthesiologie en Intensive Care van het UMC St Radboud in Nijmegen.
Hij is getrouwd met Hilde de Haan en ze hebben samen vier kinderen: Nienke (1994), Bernou (1997), Berend (2000) en Janne (2002).