10 Complications of Tracheotomy and Strategies to Avoid Them

Eckart Klemm and Andreas Nowak

10.1 Introduction

Complications in tracheotomies are defined very differently in literature according to type and severity, which makes comparability difficult and prompted Fantoni [1] to recommend internationally comparable criteria and the assignment of events and complications in PDT to the three phases of puncture, dilatation or insertion of the tracheostomy tube. This requirement is still valid today. In the present chapter, only studies that show a minimum of comparable operations and defined study criteria have been included.

Percutaneous dilatational tracheotomy is repeatedly evaluated as a simple, quick and cost-effective intervention in literature. It should be emphasized that both surgical tracheotomy and percutaneous dilatational tracheotomy require a learning curve under the supervision of trained personnel. The problem was described by Páez et al. [2] when PDT was introduced in 38 patients: The procedure was described in 60% as easy, in 30% as moderate and in 10% as difficult, accompanied by 26% bleeding requiring therapy, 29% tube punctures and two deaths due to bleeding and pneumothorax. A new analysis of tracheotomy-associated deaths also warns of misjudgments [3].

The complication density of the various tracheotomy methods is shown in the following overviews.

E. Klemm
Klinik für Hals-Nasen-Ohren Heilkunde, Kopf- und Halschirurgie, Plastische Operationen, Städtisches Klinikum Dresden, Dresden, Germany
e-mail: Eckart.Klemm@klinikum-dresden.de

A. Nowak (✉)
Klinik für Anästhesiologie und Intensivmedizin, Notfallmedizin und Schmerztherapie, Städtisches Klinikum Dresden, Dresden, Germany
e-mail: Andreas.Nowak@klinikum-dresden.de

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Table 10.1 Frequency of hemorrhage requiring therapy in tracheotomies

Authors	Number Method	Definition	Frequency (n)	Frequency (%)
Fantoni and Ripamonti [4] prospective study	109 F	"Bleeding without transfusion"	3	2.7
Muhammad et al. [5] retrospective study	497 C²	"Different medical interventions"	24	4.8
Klemm et al. [6] retrospective study	148 C²	">20 ml"	3	2.0
	142 OST		4	2.8
Dongelmans et al. [7] prospective study	128 B	">20 ml"	5	3.9
Kost [8] review	1385 C¹	"Intermediate 200 ml, intervention"	56	4.0
	852 C²		11	1.3
	337 OST		57	16.9
prospective study	500 BC²		12	2.4
Delaney et al. [9] meta-analysis	436 PDT	"Clinically relevant"	22	5.0
	425 OST		27	6.3
Diaz-Reganon et al. [10] prospective study	800 G	"25–100 ml"	14	1.7
Straetmans et al. [11] evaluation	303 OST	"Surgical exploration"	11	3.6
Fattahi et al. [12] retrospective analysis	171 OST	"Surgical exploration"	2	1.2
Halum et al. [13] survey	870 OST	"Operative note as complication"	17	1.9
	178 PDT		13	7.3
Hashemian and Digaleh [14] prospective double-blind study	160 BC¹	"Moderate 2–5 cc, severe > 5 cc"	11	6.9
Fiorini et al. [15] retrospective study	304 OST	"Event, unfavorable"	12	3.9
Decker et al. [16] prospective study	289 BC²	"Moderate, severe"	27	9.3
Pilarczyk et al. [17] retrospective study	1001 BC²	"Moderate 5–20 ml, severe 20–50 ml, major >50 ml"	88	8.8
Nowak et al. [18] prospective study	179 BC²	">10 ml and treatment required"	10	5.5
Janik et al. [19] retrospective study	1143 OST	"Surgical exploration"	31	2.7

B PDT acc. to Ciaglia Blue Rhino, *OST* open surgical tracheotomy, *G* PDT acc. to Griggs, *C¹* PDT acc. to Ciaglia with endoscopy, *C²* PDT acc. to Ciaglia without endoscopy, *F* TLT acc. to Fantoni

10.2 Intraoperative and Perioperative Hemorrhage

The professional definitions of bleeding are very inconsistent worldwide, both with regard to the quantities and the frequently used classifications of minor and major complications, which leads to a complication bias. Table 10.1 shows the complication density regarding hemorrhages requiring therapy under definition of the individual authors.

Under the clarification that there is bleeding during every operation, there is no uniform definition for the "complication of hemorrhage", which must be observed when comparing the data.

Fig. 10.1 Massive hemorrhage after injury of a thyroid ima artery with impending asphyxia during PDT with flexible endoscopy: A large coagulum in the trachea and main bronchi could only be removed in a 20-year-old patient by rigid endoscopy and powerful suction in a life-saving manner

According to Shlugman et al. [20], bleeding hazards occur when the midline is missed, which can be observed with every fifth intervention. The risk of fatal bleeding complications increases especially with punctures below the fourth tracheal ring [21]. Unknown variants in vascular courses, a thyroid ima artery and a high standing brachiocephalic trunk are of predisposing importance for severe and fatal incidents [3]. Due to possible vascular variations (Chap. 3), ultrasound examinations and endoscopies of the trachea are recommended prior to PDT. Deitmer and Delank [22], Klemm et al. [23] and Nowak et al. [18] agree that a rigid endoscopy with powerful suction must always be at hand for every method of tracheotomy (Fig. 10.1).

It is not the amount of bleeding that is decisive for the respiratory tract, but the risk of acute impairment of gas exchange.

Preoperative clinical examination, neck sonography and endoscopy with light-intense diaphanoscopy contribute to the early detection of atypical vascular routes.

10.3 Pneumothorax

A detailed description for the causes of intraoperative pneumothorax in PDT is provided by Fikkers et al. [24] and, after literature searches, mention posterior tracheal wall injuries nine times, via falsa in punctures and dilatations eight times, a barotrauma twice and tracheostomy tube dislocations four times as well as unexplained causes seven times. Norwood et al. [25] describe the case of a pneumothorax with fatal lung over-inflation as a result of a valve mechanism using a flexible endoscope in a 7.5 mm inner diameter ventilator tube Fig. 10.2 (Table 10.2). In literature searches, Oeken et al. [32] found 40 severe posterior tracheal wall injuries with 28 cases of pneumothorax. Koitschev et al. [33] determined eight pneumothorax cases in surveys. Ten tracheotomy-related deaths from pneumothorax were reported by Klemm and Nowak [3].

Fig. 10.2 High risk of pneumothorax risk due to pulmonary over-inflation as a result of hindered expiration when using flexible endoscopes in small ventilator tubes

Table 10.2 Pneumothorax through PDT and OST

Authors	Method	Frequency (n)	Frequency (%)
Fantoni and Ripamonti [4] prospective study	109 (F)	1	0.9
Norwood et al. [25] prospective study	420 (C²)	2	0.5 (1 death)
Escarment et al. [26] prospective study	162 (G)	5	3 (2 deaths)
Fikkers et al. [24] review 1986–2003	3012 PDT	31	0.8 (1 death)
Kost [8] review 1988–2003	1385 (C¹)	9	0.6
	852 (C²)	5	0.6
	337(OST)	7	2.0
Straetmans et al. [11] evaluation 1996–2005	303 (OST)	1	0.3
Trouillet et al. [27] randomized controlled trial	109 (BC²)	2	1.8
Oreadi and Carlson [28] prospective study	192 (OST)	0	
Hashemian and Digaleh [14] prospective double-blind study	160 (BC¹)	3	1.9
Nowak et al. [18] prospective study	179 (BC²)	0	
Ulkumen et al. [29] retrospective study	233 (OST)	2	0.9
Cohen et al. [30] retrospective study	256 (C¹)	2	0.8
Tamir et al. [31] retrospective study	311 (OST)	3	1

B PDT acc.to Ciaglia Blue Rhino, *G* GWDF acc. to Griggs, *OST* open surgical tracheotomy, *F* TLT acc. to Fantoni, *C¹* PDT acc. to Ciaglia without endoscopy, *C²* PDT acc.to Ciaglia with endoscopy

Beiderlinden et al. [34] see dangers of posterior tracheal wall injuries with the consequences of pneumothorax, pneumomediastinum or pneumopericardium especially in young patients with a yet soft trachea and its impressions due to bougienage processes during PDT.

An intraoperative pneumothorax in PDT is not so rare and potentially fatal. Early detection through auscultation, percussion, sonography, thorax X-ray and immediate therapy are lifesaving.

Table 10.3 Posterior tracheal wall injuries in PDT and OST

Authors	Method	Frequency	
		(n)	(%)
Norwood et al. [25] prospective study	420 (C^2)	4	0.9
Kost [8]	1385 (C^1)	3	0.2
review 1988–2003	852 (C^2)	2	0.7
	337 (OST)	0	
prospective study	500 (BC^2)	3	0.6
Remacle et al. [35] prospective study	166 (BC^2)	2	1.2
	24 (FR)	3	12.5
Straetmans et al. [11] evaluation 1996–2005	303 (OST)	1	0.3
Trouillet et al. [27] randomized controlled trial	109 (BC^2)	1	0.9
Oggiano et al. [36] retrospective study	209 (C^2)	11	5.3
	169 (OST)	0	
Nowak et al. [18] prospective study	179 (BC^2)	2	1.1

B PDT acc. to Ciaglia Blue Rhino, *C^1* PDT acc. to Ciaglia without endoscopy, *OST* open surgical tracheotomy, *FR* PDT acc. to Frova, C^2 PDT acc. to Ciaglia with endoscopy

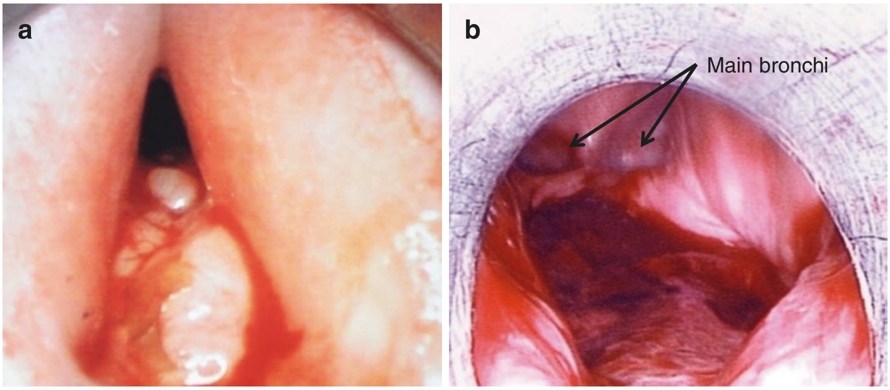

Fig. 10.3 (**a, b**) Posterior tracheal wall injuries levels I and II**,** as a result of PDT despite flexible endoscopic control

10.4 Posterior Tracheal Wall Injuries

Posterior tracheal wall injuries occur in both percutaneous dilatational tracheotomies and surgical tracheotomies (Table 10.3) and may occur harmlessly as superficial mucous membrane injuries and severely in the form of ruptures resulting in tracheoesophageal fistulas Fig. 10.3.

Therefore, Ciaglia warned in [37] against the use of rigid single dilators for PDT remarking that “The day of the rigid dilator... is over”.

In Table 10.3 Six authors did not report any severity levels Chap. 11.

In a Rapitrac PDT, Kedjanyi and Gupta [38] describe a rupture of the trachea in 75% of the circumference and Gomez-Caro et al. [39] defects of the trachea of

2–4 cm in length in the cervical and thoracic trachea by PDT, also with fatal outcome. In the result of a survey, Dost and Koeser [40] reported six posterior tracheal wall injuries and seven tracheoesophageal fistulas, Delank et al. [41] reported five severe tracheal lesions requiring surgery after PDT. For diagnostic and therapeutic options, please refer to Chap. 11.

Only an endoscopy with a clear overview and the control of the surgeon by the endoscopist, the use of suitable PDT sets as well as endoscopic control of the upper and lower trachea can prevent posterior tracheal wall injuries or detect them early.

10.5 Intraoperative Loss of the Airway

In all methods of percutaneous dilatational tracheotomy, the ventilation tube must be retracted into the laryngeal plane for the purpose of PDT. Regarding this situation, Rieger [42] formulated as follows, "It is recommended that the cuff of the endotracheal tube is unblocked, and the tube is withdrawn under direct laryngoscopic control until the cuff lies above the vocal cords. The cuff shall now be blocked again above the vocal folds. Here at the latest, the safe control of the airway with the endotracheal tube is abandoned. In this position, there is a danger of dislocation with the risk of loss of the airway and the danger of aspiration. The endotracheal tube must be held in this position by an assistant while the transtracheal puncture is performed." (Fig. 10.4a, b, Table. 10.4).

The intraoperative loss of the airway is methodically possible when PDT is performed with flexible endoscopes, regardless of the type of PDT performed. A ready-to-use and fast possibility for reintubation is required.

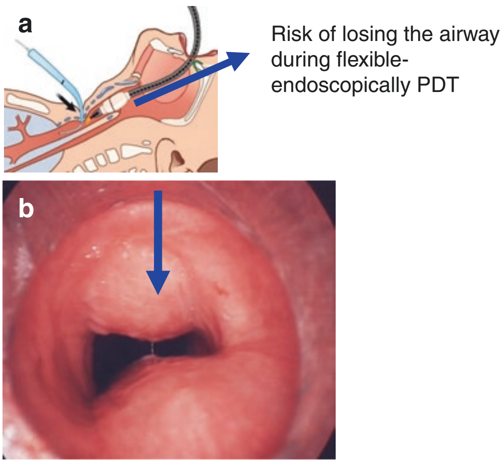

Fig. 10.4 (**a**, **b**) Danger of loss of the airway during flexible endoscopic controlled PDT

Table 10.4 Intraoperative loss of the airway during PDT

Authors	Method	Frequency (n)	(%)
Fantoni and Ripamonti [4] prospective study	109 (F)	3	2.7
Escarment et al. [26] prospective study	162 (G)	12	7.4
Norwood et al. [25] prospective study	420 (C^2)	3	0.7
Gambale et al. [43] prospective study	181 (C^2)	3	1.7
Kost [8] prospective study	500 (C^2)	3	0.6
Altmann et al. [44] prospective study	214 (G)	6	2.8
Terragni et al. [45] randomized controlled trial	419 (G+FR)	5	1.2
Hashemian and Digaleh [14] prospective double-blind study	160 (BC^1)	3	1.9
Hazelton et al. [46] prospective study	184 (C^2)	2	1.1
Nowak et al. [18] prospective study	179 (BC^2)	0	
Cohen et al. [30] retrospective study	256 (C^1)	2	0.8

C PDT acc. to Ciaglia, *F* TLT acc. to Fantoni, *C^1* PDT acc. to Caglia without endoscopy, *FR* PDT acc. to Frova, *B* PDT acc. to Ciaglia Blue Rhino, *G* GWDF acc. to Griggs, *FR* PDT acc. to Frova, *C^2* PDT acc. to Ciaglia with endoscopy

Table 10.5 Loss of the airway during tracheostomy tube exchange/decannulation

Authors	Method	Frequency (n)	(%)
Massick et al. [47] prospectively randomized trial	50 (C^2)	4	8 (1 death)
	50 (OST)	0	
Kost [8] review	2541 (C^1 C^2)	26	1.0
	337 (OST)	6	1.8
Fattahi et al. [12] retrospective study	171 (OST)	2	1.2
Fiorini et al. [15] retrospective study	304 (OST)	6	1.9
Cohen et al. [30] retrospective study	256 (C^1)	20	7.8
Tamir et al. [31] retrospective study	311 (OST)	20	6
Ulkumen et al. [29] retrospective study	233 (OST)	7	3
Liao et al. [48] retrospective study	1000 (OST)	40	4

C^1 PDT acc. to Caglia without endoscopy, *C^2* PDT acc. to Caglia with endoscopy, *OST* open surgical tracheotomy

10.6 Perioperative and Postoperative Loss of Airway

Further latent dangers consist in the loss of the airway during tracheostomy tube change due to a "shifting-closure-phenomenon", through accidental decannulation or closure of tracheostomy tube by blood clots and mucus plugs. The term "shifting-closure-phenomenon" refers to the displacement of pretracheal tissue layers, in which parts of fat, thyroid gland, muscles and fascia can immediately lay over the stoma after decannulation, making recannulation more difficult or impossible. The risk is greatest in the early postoperative period (Table 10.5).

No tracheostomy tube change after PDT without a light source (headlamp), guide catheter, speculum (Killian Nasal-Struycken Speculum® with long blades or

Tracheal Dilator Trousseau®) as well as the possibility of re-intubation in stand-by. The same requirements also apply to stomata according to OST.

10.7 Tracheal Ring Fractures

There are different views on the significance of tracheal ring fractures between the fields of intensive care medicine and laryngology. This is due to the fact that the incidence of tracheal ring fractures after surgical tracheotomy plays a minor role in a retrospective literature analysis by Straetmans et al. [11] and Fiorini et al. [15] at 0.9% and 0.6%, respectively, while tracheal ring fractures are a frequent event in both autopsy findings and endoscopic findings after PDT if they are systematically searched for by Nowak et al. [18] and Byhahn et al. [49]. The current type of flexible endoscopically controlled PDT does not reveal an obligatory search, as numerous clinical studies show. Dislocated tracheal rings do not usually lead to tracheal stenosis until 5–12 weeks after epithelization and scar formation [50]. These are periods of time after which patients have long disappeared from the intensive care medicine, and when diagnostics and therapy of tracheal stenoses are assigned to the specialties of laryngology, thoracic surgery or pneumology (Chap. 12). The tracheal braces with their different anatomical variants and histological tissue formations (Chap. 4) tend to fracture during powerful compression during bouginage in PDT, independent of the method described. Van Heurn et al. [51] described necrosis and ossification processes on injured tracheal braces, especially from the 3rd week after PDT.

Walz and Schmidt [52] describe a particular tendency to vertical tracheal ring fractures of 1 to 2 adjacent braces in autopsy findings. There are currently no systematic studies available on when and under what circumstances tracheal fractures lead to tracheal stenoses requiring treatment [53] (Fig. 10.5a, b, Table 10.6).

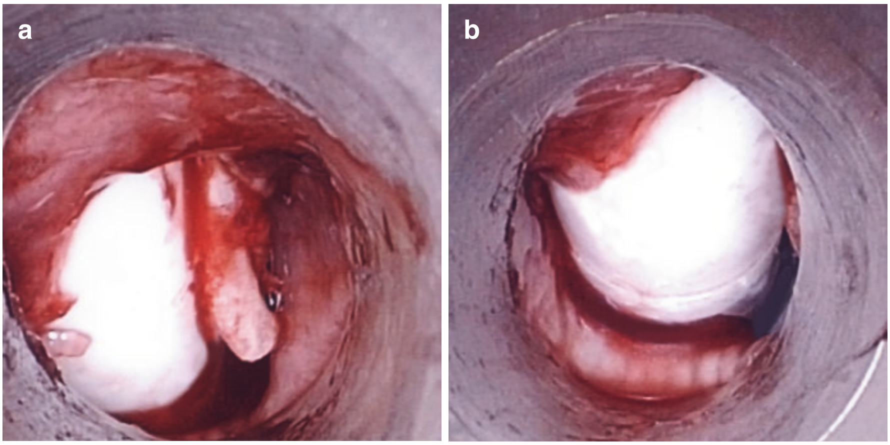

Fig. 10.5 (**a, b**) Tracheal ring fracture during PDT. Immediate endoscopic therapy by TED for the necessary prophylaxis of tracheal stenosis

Table 10.6 Tracheal ring fractures in various methods of tracheotomy

Authors	Method	Frequency (n)	Frequency (%)
Walz and Schmidt [52] clinical-pathological study	42 (C), post mortem autopsy findings trachea	12	28.6
Dollner et al. [54] retrospective study	19 (G) by way of postoperative endoscopy after 17 months, cricoid lesions	7	32
Frova and Quintel [55] prospective study	50 (FR) intraoperative endoscopy	4	8
Higgins et al. [56] prospective study	132 (FR)	12	9.1
	75 (B)	4	5.3
Straetmans et al. [11] Evaluation	303 OST	3	0.9
Dempsey et al. [57] prospective study	576 (B)	56	9.7
McCague et al. [58] retrospective study	426 (BC^2)	63	14.8
Fiorini et al. [15] retrospective study	304 OST	2	0.6
Ferraro et al. [59] retrospective study	219 (B/FR/D)	21	9.6
Decker et al. [16] prospective study	289 (BC^2)	18	6.2
Nowak et al. [18] prospective study	179 (BC^2)	30	17.1

B PDT acc. to Ciaglia Blue Rhino, *C* PDT acc. to Ciaglia, C^2 PDT acc. to Ciaglia with endoscopy, *FR* PDT acc. to Frova, *OST* open surgical tracheotomy, *G* GWDF acc. to Griggs, *D* PDT Ciaglia Blue Dolphin

The high number of fractures detected by Nowak et al. [18] is the result of a targeted search by study protocol in a multi-center interdisciplinary study.

Dislocated tracheal ring fractures must be expected with every percutaneous dilatational tracheotomy. Cartilage and bone splinters must be subjected to immediate endoscopic therapy to prevent later tracheal stenosis. If this is not successful, early surgical intervention is indicated.

10.8 Tracheal Stenoses

The late complication of the development of tracheal stenosis requiring therapy, usually lumen constriction from 60 to 70% up to total occlusion (grade III and IV according to Myer and Cotton), is a feared event. This circumstance is very unfortunate for the patient, as all the effort of the original rehabilitation is lost and the patient is again hospitalized with surgical and rehabilitative measures, including conditions of shortness of breath and anxiety (Table 10.7).

The widely differing definitions make comparability of the follow-up examinations difficult. The classification of degrees of severity of tracheal stenosis [70] was ignored.

Table 10.7 Tracheal stenoses after PDT and OST

Authors	Number	Method	(Stenoses definitions) Stenosis n	(%)	Time of control	Type of control
van Heurn et al. [51] retrospective study	p 123	PDT (C)	*(Stenosis 25–50%)*		5–53 months	CT neck, check voice function
	f 80		2	2.5%		
			(Stenosis 50–75%)			
			1	0.8%		
Hill et al. [60] prospective study	p 353	PDT(C)	*(Symptomatic stenosis)*		10 months	Telephone interview, clinical doctor's visit
	f 214		8	3.7%		
Law et al. [61] prospective study	p 109	PDT (C)	*(Stenosis >40%)*		6 months	Questionnaire, telephone interview, spirometry, endoscopy
	f 41		1	2.4%		
Rosenbower et al. [62] prospective study	p 95	PDT (C)	*(Subglottic stenosis)*		12 months	Endoscopy ENT doctor, telephone interview
	f 55		2	2%		
Walz et al. [63] prospective study	p 337	PDT (C)	*(Stenosis > 50%)*		6 months	Clinical doctor's visit, X-ray check
	f 106		4	3.7%		
Norwood et al. [25] prospective study	p 422	PDT (C)	*(Stenosis > 50%)*		26 months	Telephone interview, endoscopy, CT neck
	f 100		3	3%		
Escarment et al. [26] prospective study	p 162	GWDF (G)	*(Stenosis with surgery)*		3 months	Clinical visit, endoscopy, telephone interview
	f 81		4	4.9%		
Kearney et al. [64] prospective study	p 824	PDT (C)	*(Stenosis with surgery)*		12 months	Type of control, not specified
	f 548		9	1.6%		
Dollner et al. [54] retrospective study	p 60	GWDF (G)	*(Stenosis > 25–50%)*			Telephone interview
	f 19		2	3.3%		
			(Stenosis > 50%)		17 months	Doctor interview, endoscopy
			1	1.6%		
Jung et al. [65] retrospective study	p 419	OST visor tracheotomies	*(Stenosis > 25–50%)*		6 months	ENT examination, endoscopy
	f 93		3	3.2%		

Young et al. [66] prospective study	p 120	PDT (B)	*(Stenoses > 46%)*		3 months	Questionnaire, MRT, spirometry
	f 50		5	4%		
Lopez-Pastorini et al. [67] retrospective study	p 401	OST *(degree of stenosis unspecified)*	92 surgical stoma occlusion		3 months	Clinical visit, endoscopy
	f 155		3	3.3%		
			63 spontaneous occlusions			
			14	22.2%		
Dempsey et al. [68] review, pooled estimate % (95%CI)		418 OST	11	2.8%	Not specified	Type of control + degree of stenosis, not specified
		1831 PDT(G)	10	0.9%		
		1546 PDT(C)	15	1.0%		
		1474 PDT(B)	7	0.6%		
		124 TLT(F)	1	1.5%		
Araujo et al. [69] prospective study	p 114	PDT (D)	(*Stenosis > 50%)*		7 months	CT, endoscopy
	f 52		2	3.7%		
Janik et al. [19] retrospective study	p 1143	OST	*Surgical Intervention*		8 weeks	Clinical visit, endoscopy, MRT/CT
	f 435		6	1.4%		

B PDT acc. to Ciaglia Blue Rhino, *C* PDT acc. to Ciaglia, *G* GWDF acc. to Griggs, *Fr* PDT acc. to Frova, *D* PDT Ciaglia Blue Dolphin, *p* number of primary PDT, *OST* open surgical tracheotomy, *f* number of follow-up examinations, *F*: TLT Fantoni

The causes of tracheal stenoses are complex and usually based on a combination of tracheal trauma, inflammation and foreign body irritation with tissue formation (granulation) at predisposed sites above, next to and below the stoma with loss of the original tracheal tissue layer by fibrosis.

The ring cartilage reacts particularly sensitively to traumas and injuries with the development of recurrent tracheal stenoses, caused by excessive regeneration processes with osteoid expression of the osteoblasts and mineralization in an acidic environment. According to Nicolli et al. [71], independent of the tracheotomy method, overweight, diabetes and reflux with chronic inflammatory reactions are risk factors for the development of subglottic stenoses. Gadkaree et al. [72] extend the disposition to laryngotracheal stenoses by the co-morbidities COPD, nicotine abuse, OSAS as well as hypertension and microcirculation disorders after an analysis of 262 stenoses patients.

Between 1996 and 2016, a total of 102 patients with tracheal stenoses requiring therapy (aged 17–89, average age 60 years) were observed in the hospital's own patients of the University Teaching Hospital Dresden-Friedrichstadt. These were patients from 20 clinics who became conspicuous during rehabilitation several weeks after tracheotomies with shortness of breath. The occurrence of this stenosis was recurrent in 75 PDT but also in 27 OST with too high tracheostomata with injuries of the ring cartilage and/or associated with dislocated cartilage fractures left behind. One hundred and fourty-eight follow-up operations with therapy costs of Euro 1,174,850 were necessary (Fig. 10.6).

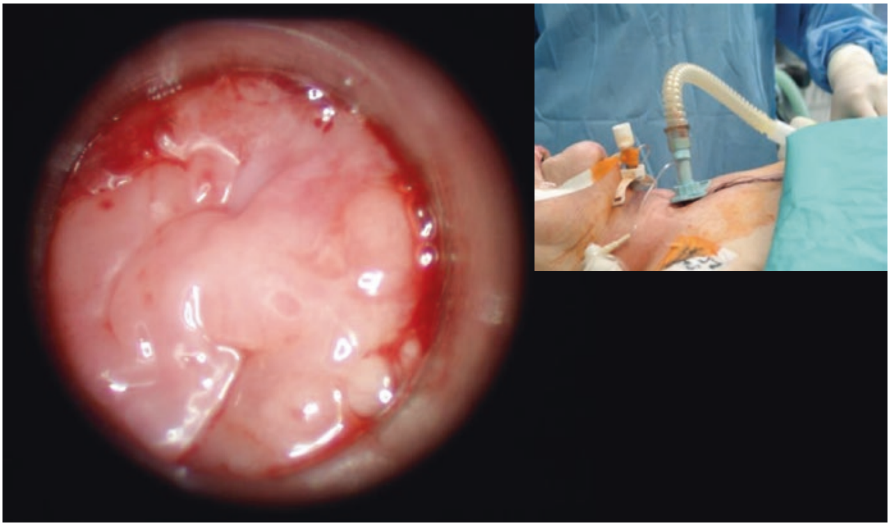

Fig. 10.6 Total laryngeal atresia by via falsa in PDT: puncture, dilatation and insertion of the tracheostomy tube over the hyoid bone with subsequent total destruction and firm adhesions of the laryngeal internal structures, additionally upper tracheal stenosis Myer-Cotton IV. The patient did not survive the underlying brain tumor disease

For whatever reason, there is no indication for a tracheotomy that is supposedly "necessarily" too high, as is occasionally published in the literature. The safest prevention for later tracheal stenoses is a gentle atraumatic procedure at the right place between the 2nd and 4th tracheal braces in the midline, use of atraumatic ready sets for PDT and tissue-friendly, adapted tracheostomy tubes, therapy of infections and granulations, regular tracheostomy tube and skin care, therapy with existing reflux and continued controls with remaining tracheostoma.

10.9 Stoma Infections

There is a general opinion that surgical tracheotomies have a higher postoperative infection rate than PDT. There are no scientifically based studies on the causes. Wound infections in the stoma area are not defined in the literature (Table 10.8).

For the therapy of wound infections, please refer to Chap. 18.

10.10 Stoma Metastases

According to a study by Knipping et al. [73] using 58 PDT after Ciaglia and 17 PDT after Fantoni for malignant tumors in the mouth, larynx and throat, two cases of stomametastases with fatal outcome occurred according to the TLT Fantoni method, which is why this combination is strongly discouraged.

Table 10.8 Wound infections [8][a], [68][b]

			Infektionen	
Method	Number of tracheotomies		n	%
OST[a]	337		43	12.7
PDT (C^1)[a]	1547		21	1.3
PDT (C^2)[a]	994		16	1.6
OST[b]	418		36	8.5
PDT (G)[b]	1666		16	1.5
PDT(C)[b]	1355		11	1.0
PDT (B)[b]	554		6	1.7
TLT (F)[b]	124		4	3.9
Tamir et al. [31]	311	OST	11	3.5
Ulkumen et al. [29]	223	OST	8	3.6
Cohen et al. [30]	256	C^1	17	6.6

OST open surgical tracheotomy, *PDT (B)* PDT acc. to Ciaglia Blue Rhino, *C^1* PDT acc. to Caglia without endoscopy, *PDT(G)* PDT acc. to Griggs, *PDT(C)* PDT acc. to Ciaglia, *TLT(F)* TLT acc. to Fantoni, *C^2* PDT acc. to Ciaglia with endoscopy

[a]Review

[b]29 studies, evaluated via "pooled estimate (95-%-CI)"

10.11 Tracheotomy-Related Deaths

While publications on tracheotomies have increased in recent years under various scientific aspects, communications on tracheotomy-related deaths have been published only sporadically, which is why Klemm and Nowak [3] conducted a systematic review for PDT and OST for the period 1990–2015.

In 109 publications from 21 countries with a total of 25,056 tracheotomies, including 16,827 PDT, 7,934 OST and 295 tracheotomies with no descriptions of the method, 352 tracheotomy-related deaths were found, corresponding to a total frequency of 1.4%, for PDT 0.67% (95-%-CI: 0.56; 0.81), for OST 0.62% (95-%-CI: 0.47; 0.82).

The main causes for death were bleeding (PDT 0.26%, OST 0.26%), loss of the airway (PDT 0.20%, OST 0.21%) and via falsa (PDT 0.20%, OST 0.11%). Disposing factors for deaths were variations of large blood vessels and variations of the anatomy, missing or insufficient overview in flexible endoscopy, loss of the respiratory tract, via falsa resulting in bleeding, pneumothorax and tracheoesophageal defects, sometimes in combination. Other causes for death were inadequate strategies to control complications, such as severe bleeding and pneumothorax. Too caudal tracheotomies are a high-risk factor for tracheoinominate fistula (TIF) or, synonymously, tracheaoarterial fistula (TAF). A review of the last 15 years showed a fatal outcome 77%, despite emergency intervention [74]. In addition, other risk factors are inexperience of the actors and insufficient knowledge of respiratory physiological peculiarities in tracheotomized patients and accessories in the clinic and outpatient area.

Caution! Danger of pneumothorax and death! The application of a speaking valve demands prior complete cuff-deflation whenever a cuffed tracheal tube is used [75].

Tracheotomy-related deaths are underreported worldwide [76].

Conclusions for practice

- *The frequency of tracheotomy-related deaths is similar for PDT and OST.*
- *Deaths are caused by complications, the avoidance and control of which must be taken into account both during planning and aftercare, also from the point of view of medical law.*
- *The use of a checklist makes sense.*
- *The formation of a stoma lower than the fourth tracheal brace should be omitted; dangerous areas of the vascular anatomy can be reached.*
- *Heavy bleeding to the outside must be treated surgically. For internal bleeding, securing the airways has absolute priority. Rigid endoscopy with powerful suction must be readily available.*
- *Despite methodological weaknesses via falsa and flexible endoscopy are not mutually exclusive.*
- *Early detection of pneumothorax can save lives.*
- *Tracheotomies, regardless of the PDT or OST method, are not beginner operations and must be learned under the guidance of experienced physicians.*
- *Tracheostomy tube management requires special knowledge and experience.*

10.12 Avoidance and Reduction of Complications by the Rigid Tracheotomy Endoscope for Dilatational Tracheotomies (TED)

Whereas rigid tracheobronchoscopy was a common aid in the hands of the anesthetists and intensive care therapists decades ago, this management has almost been lost with the development of flexible endoscopes.

The design of the rigid tracheotomy endoscope has been adapted to the modern requirements of respiratory medicine and combines the advantages of rigid endoscopy with the aim of better controlling and reducing known and severe complications in percutaneous dilatational tracheotomies. Any current method of PDT can be performed with the endoscope in a controlled manner. The method is easy to learn.

This technique has been introduced into the endoscopy of ENT medicine by Klemm [77, 82] and adopted by Nowak et al. [78, 79] into the practice of anesthesia/intensive care.[1]

10.12.1 Percutaneous Dilatational Tracheotomy with the Tracheotomy Endoscope, Practical Execution in Seven Steps

Step 1 Endoscope Insertion
Preoperative control on the basis of the "Surgical Safety Checklist" of the WHO and determination of the external landmarks, the disinfection of the neck and cleaning of the mouth and throat is carried out with the installation of a silicone dental protector in the upper jaw. The rigid endoscope is carefully inserted into the larynx entrance along the lying tube via the right corner of the mouth under sight (Fig. 10.7).

The patient's endotracheal tube is the guidance when the endoscope is inserted.

Step 2 Extubation/Intubation
With recognition of the laryngeal structures, the lying tube is unblocked by an anesthesia nurse. The endoscopist removes the endotracheal tube step by step with his left hand and simultaneously inserts the rigid endoscope into the larynx and trachea with his right hand under direct vision. Then the endoscope is connected to the ventilator (IPPV or JET). The connection of a monitor system with image transmission and respiratory gas monitoring is possible (Fig. 10.8).

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[1] *Tracheotomy endoscope for dilatational tracheotomies (TED acc. to KLEMM): Manufactured by Karl Storz GmbH Tuttlingen, Germany, patented Nov 30, 2006, USA Pub. No. US2006/0270907A1 by Karl Storz GmbH Tuttlingen.*

EC Declaration of Conformity: Karl Storz GmbH Tuttlingen, Oct 16, 2008, Endoscopes E, F, G.

Tracheoscope acc. to ALOY-KLEMM: Manufactured by Carl Reiner GmbH Wien, Austria, adapted to TwinStream™ Multi Mode Respirator made by Carl Reiner GmbH, Declaration of Product Compatibility, Vienna, Jan 28, 2008.

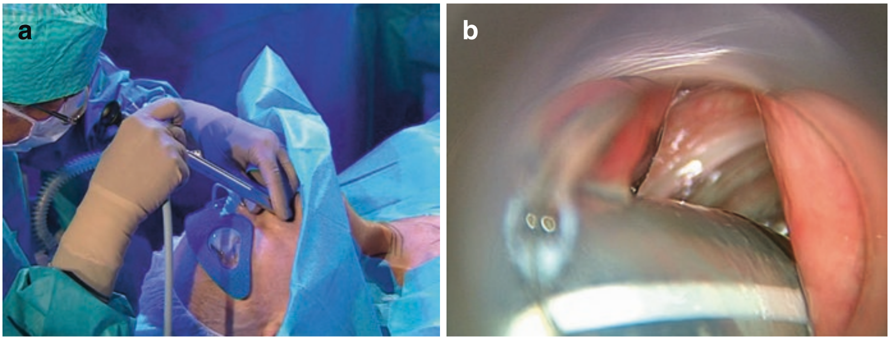
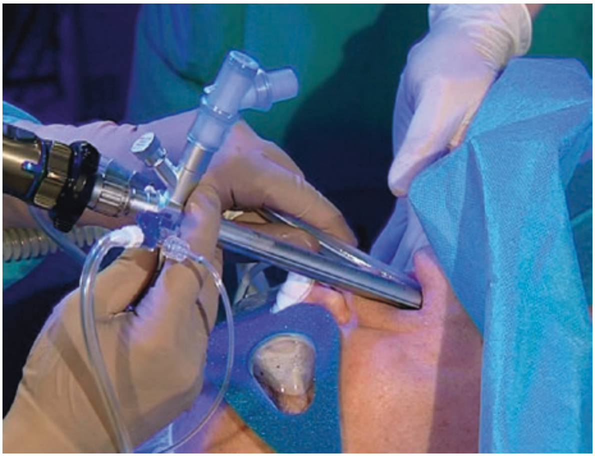


Fig. 10.7 (**a, b**) Rigid endoscope insertion under sight. The endotracheal tube is the guidance!

Fig. 10.8 The endotracheal tube is removed by the endoscopist simultaneously with the insertion of the rigid endoscope into the larynx under direct vision



With IPPV via a rigid endoscope, the leakage can be reduced using a tamponade around the endoscope with a narrow gauze bandage. However, in the case of jet ventilation, the leakage around the rigid endoscope must be maintained to exhaust respiratory gases. A tamponade around the endoscope is prohibited in jet ventilation due to the risk of air trapped with a subsequent pneumothorax.

The processes of extubation (endotracheal tube) and intubation (rigid tracheotomy endoscope) must not be separated in time.

Step 3 Clarification of the Internal Anatomy/Topography

If necessary, the trachea is cleaned by suction from secretion to the main bronchi. The trachea is then optically inspected with exact determination of the clearly visible tracheal braces 1 to 4 with deliberate identification of the ring cartilage not to be affected during tracheotomy, with possible displacement of the trachea (goiter) and possible pulsating protrusion of the brachiocephalic trunk (Arteria anonyma) (Fig. 10.9).

The internal anatomy is of equal obligatory importance as the external anatomy of the neck. The higher the body mass index, the more the topography of the inner trachea gains in importance.

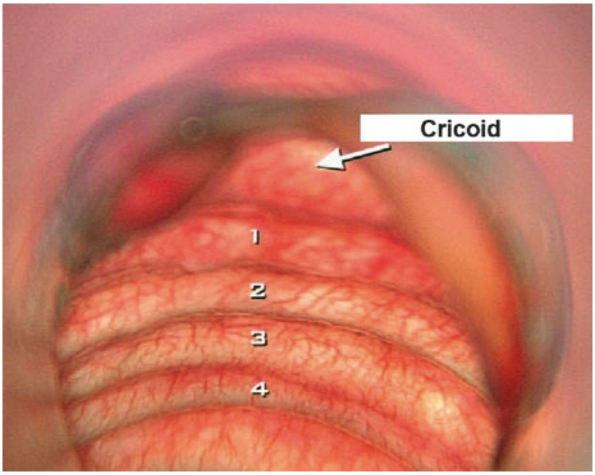


Fig. 10.9 The correct place for tracheotomy is between the second and fourth tracheal braces

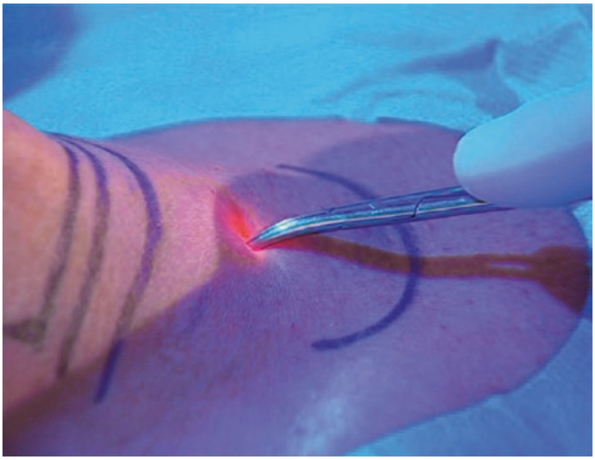


Fig. 10.10 Bright diaphanoscopy provides security in orientation

Step 4 Diaphanoscopy and Puncture
A rigid diaphanoscopy rod, which is specially bent at the front and brightly shining, has been developed for the endoscope (Karl Storz GmbH Tuttlingen Germany), which enables brightly lit diaphanoscopy and, in individual cases, the detection of large vessels in the intended tracheotomy area. The puncture of the trachea takes place in the center of the light cone in harmonious consultation between endoscopist and surgeon between the second and fourth tracheal braces. The endoscopist always controls the surgeon. If the puncture needle is placed on a tracheal brace, it must be corrected by a few millimeters downwards or upwards with only a slight retraction of the needle to reach the space between two tracheal braces in the midline. The Seldinger wire is inserted through the puncture needle. There is a sufficiently large skin incision horizontally next to the needle, possible is also a blunt spreading (Figs. 10.10 and 10.11).

Bright diaphanoscopy facilitates the view on prescribed ways. The surgeon must follow the instructions of the endoscopist.

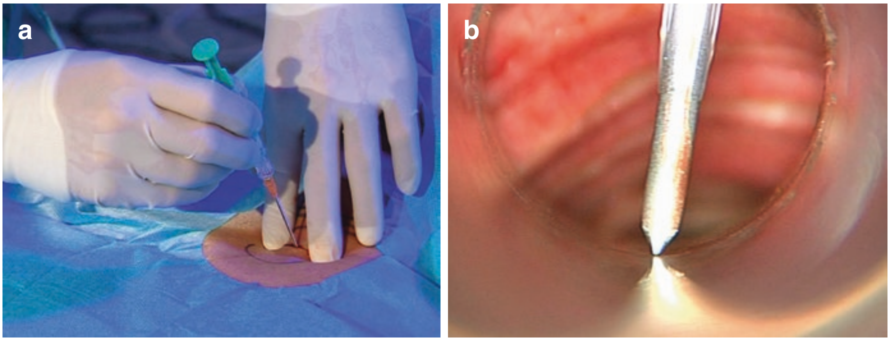


Fig. 10.11 (**a, b**) Puncture of the trachea. The extended rear tube lip of the TED protects the posterior tracheal wall from injury

Fig. 10.12 Bougienage of the trachea under sight with a conical single dilator

Step 5 Bougienage

Bougienization takes place from the outside under continuous ventilation, whereby any commercially available ready set is suitable for PDT. The rigid endoscope stabilizes the trachea from the inside and protects the posterior tracheal wall (Fig. 10.12).

Bougienage must be carried out with “gentle force”" adapted to the vulnerable trachea under continuous visual control by the endoscopist.

Step 6 Insertion of the Tracheostomy Tube

Taking age, gender and body height into consideration, the appropriate—stepless, if possible—tracheostomy tube is inserted into the trachea and blocked under endoscopic vision. Ventilation is transferred from the endoscope to the fixed tracheostomy tube. Auscultation is used to check lateral equidistant ventilation and monitoring of the E_TCO_2 is used to verify the endotracheal position of the tracheostomy tube. In case of ambiguities, the position of the tracheostomy tube is checked flexibly endoscopically, also with regard to the distance to the bifurcation (Fig. 10.13).

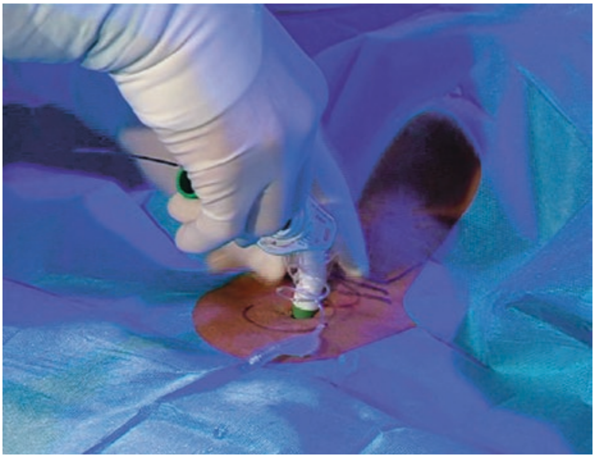


Fig. 10.13 Controlled insertion of the tracheostomy tube

Step 7 Check of Upper Trachea, Larynx and Dental Status
After determining optimal equidistant ventilation via the tracheostomy tube, the rigid endoscope is slowly withdrawn into the laryngeal plane with inspection regarding possible pathological changes of the trachea (dislocated fragments of tracheal braces) and regarding long-term intubation damage of the larynx. It is necessary to check the dental status. Tooth damage can be expected in 0.15% of cases with rigid tracheobronchoscopy [80]. Do not forget to remove foreign objects, e.g. tooth protection, tamponade.

Immediate therapy of possible pathological changes (granuloma formation, tracheal fractures) is possible and recommended without delay through the rigid endoscope.

Every elective tracheotomy requires preoperative clarification and postoperative documentation (surgical report).

10.12.2 What Are the Advantages for Avoiding and Reducing Complications in Percutaneous Dilatational Tracheotomies Using the Rigid Tracheotomy Endoscope (TED)?

- Optimum ventilation of the intensive care patient is possible during the entire tracheotomy process. Superimposed High-frequency Jet Ventilation SHFJV® has proven to be particularly effective, Chap. 16.
- No loss of airway during PDT. The rigid tracheotomy endoscope secures the airway during all individual steps. Loss of the airway is practically impossible.
- Optimum protection of the posterior tracheal wall. The tracheotomy endoscope is designed in such a way that an extended rear tube lip deliberately protects the posterior tracheal wall from injury right from the start during puncture, dilatation and tracheostomy tube insertion. Severe tracheal posterior wall injury with tracheoesophageal fistula is avoided.

- The rigid tracheotomy endoscope forms an abutment when bougienage and tracheostomy tube insertion into the trachea are necessary and prevents tracheal lumen loss and lateral compression.
- The excellent overview through a rigid endoscope with bright illumination of the entire trachea up to the bifurcation allows optimal execution of the tracheotomy with early detection of malfunctions and via falsa with the danger of a pneumothorax or a tracheoesophageal fistula.
- In the event of unforeseen significant bleeding, blood suction via a rigid endoscope with metal suction cups is much more effective than suction via flexible endoscopes, which can save lives. According to own experimental studies, the better capacities of blood suction with a correspondingly long metal suction cup differ from those of flexible endoscopes by 70%. Light bleeding can be stopped endotracheally with a curved special coagulation suction device.
- In the case of massive bleeding, immediate reintubation through the endoscope is possible with a cuff that can be placed under sight at or under the bleeding source to secure the airway.
- Dislocated tracheal braces and fragments as well as granulomas in the larynx can be treated endoscopically immediately to prevent later stenosis.
- Continuous breathing gas monitoring is possible [18, 81].
- The possibility of stent implantation exists.
- The entire tracheotomy process can be demonstrated via image monitoring for teaching purposes and documented by images for the patient file.
- All parts of the endoscope are easily accessible for cleaning and can be sterilized.
- The use of the rigid endoscope complies with the 2015 German guidelines for tracheobronchoscopy [83].

Note: From 2006 to 2010, the rigid Tracheotomy Endoscope (TED) was used in a multicenter study under the positive vote of the Ethics Committee of the Saxon Medical Association (EK-MPG-09/06-1) in 180 patients of intensive care medicine and ENT medicine on the basis of a study protocol based on Fantoni [1]*, published by Nowak et al.* [18].

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