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Pediatric tracheotomy: A 30-year experience☆,☆☆,★

Lorraine de Trey[a], Enrique Niedermann[a], Daniela Ghelfi[b], Andreas Gerber[c], Claudine Gysin[a,*]

[a]*Department of Otolaryngology, University Children's Hospital Zurich, Switzerland*
[b]*Department of Intensive Care, University Children's Hospital Zurich, Switzerland*
[c]*Department of Anesthesiology, University Children's Hospital Zurich, Switzerland*

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Abstract

Background/Purpose: The aim of this study was to investigate changes of pediatric tracheotomy practice over time.

Methods: A retrospective analysis of all tracheotomies at the University Children's Hospital Zurich from January 1990 to December 2009 was performed. Data analyzed included the indication for tracheotomy, patient comorbidities, age, duration of cannulation, and complications. The second part of the study consisted of comparing our results with data from an earlier study done at the same institution by Simma et al. (*Eur J Pediatr* 1994;153:291–296) reviewing the patients with tracheotomies treated from 1979 to 1989.

Results: Between 1990 and 2009, 119 patients were included. The indication for tracheotomy was airway obstruction in 70% and prolonged ventilation in 30%. 70% of the patients were operated on before 1 year of age. Serious postoperative complications occurred in 25 patients (23%). There was one death related to tracheotomy. Successful decannulation was achieved in 60%, on average 28 months after tracheotomy. The decannulation rate in patients with airway obstruction was 74% compared to 52% for the patients in prolonged ventilation group; a statistically significant difference was observed ($p<0.05$). The longitudinal analysis showed an increase of indications for prolonged ventilation and a trend toward decreased tracheotomy complications.

Conclusion: Over 30 years, a shift in the indications of pediatric tracheotomy, with an increasing number of procedures performed for prolonged ventilation, was found. The tracheotomy-related mortality was under 1%. Tracheotomy remains a valid and safe option for pediatric patients.

Level of evidence 2c.

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Tracheotomy has been performed since ancient times. The first opening of the trachea is credited to Asclepiades (100 BC), but the outcome is unknown. Paul d'Egine reported the first successful tracheotomy in the 16th century. This procedure continued to be feared for centuries, and reserved only for desperate cases. Armand Trousseau, during the diphtheria epidemic in the 19th century, popularized

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* Corresponding author. Tel.: +41 44 266 7656; fax: +41 44 266 8143.
E-mail address: claudine.gysin@kispi.uzh.ch (C. Gysin).

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tracheotomy as a life-saving procedure. At the beginning of the 20th century, Chevalier Jackson, in a landmark paper, described the technique of tracheotomy, which is still in use today [1].

Numerous papers have been published on adult tracheotomy, its indications, the operative technique, and complications, but the literature is much scarcer regarding pediatric tracheotomy. In the past, the most common indication for pediatric tracheotomy was acute inflammatory airway obstruction. With the development of vaccination against *Haemophilus influenzae* and *Corynebacterium diphteriae*, this indication has almost disappeared. Advances in the materials for endotracheal intubation, allowing for prolonged intubation without laryngotracheal damage, devices which permit intubation of difficult airways, and the development of the pediatric intensive care units had led to a change of the indications for pediatric tracheotomy. As a result, fewer tracheotomies might be performed in the pediatric population [2]. The two main indications for pediatric tracheotomy remain to be upper airway obstruction and prolonged ventilation. The latter includes mostly chronic patients, who tend to be tracheotomized for longer periods of time or even not to be decannulated at all.

The present study reviews data of the patients who underwent a tracheotomy from 1990 to 2009 at the University Children's Hospital Zurich and compares the results with data from an earlier study done at the same institution. In 1994, Simma and colleagues [3] from University Children's Hospital Zurich published a paper on tracheotomy in children, which evaluated a 10-year time period from 1979 to 1989. In order to compare similar time frame durations for this longitudinal analysis, the recent group was subdivided in to two groups: 1990–1999 (group B) and 2000–2009 (group C). A longitudinal analysis is done to assess changes in indication, age at the time of operation, duration of cannulation, decannulation, morbidity and mortality during these 30 years' period of time.

1. Methods

This is a retrospective analysis of all tracheotomies performed at the University Children's Hospital Zurich from January 1990 to December 2009. Patients were identified by reviewing all the anesthesia protocols between 1990 and 2002 and from a prospective database established in 2002. Overall, 122 consecutive patients were identified. Three patients had to be excluded, two because their chart specified that parents refused participation in any study, and one because the patient's chart was unavailable. Inpatient and outpatient charts of the remaining 119 children were analyzed.

This study was conducted according to the Declaration of Helsinki. The study was conducted in agreement with institutional guidelines for retrospective studies approved by the institutional review board.

Elective tracheostomy technique involved removing the anterior aspect of the second tracheal ring. No sutures were placed between the trachea and skin. The cannula was sutured to the skin and tight ties were placed. The patients are kept in the intensive care unit until the first cannula change, which is done by the surgeon. If otherwise not contraindicated, patients are then transferred to an intermediate care unit where they stay until discharge from the hospital. Parents were trained to care for the tracheotomy, including suctioning, cannula change, and learn cardiopulmonary resuscitation. The whole process takes between 4–8 weeks, depending on the learning abilities of the parents. The patients are discharged home when parents can provide care independently for 24 h. All necessary equipment is provided and home nursing support organized if needed. The oxygen saturation is monitored at night. Follow-up checks are carried out regularly. A yearly bronchoscopy is performed to look for granuloma and to adjust tube size.

Data extracted include indication for tracheotomy, patient comorbidities, age at the time of operation, duration of cannulation, and complications. The indication for tracheotomy was divided into airway obstruction and prolonged ventilation. No tracheotomy was solely performed for broncho-aspiration or "poor pulmonary toilette." The airway obstruction group was subdivided into craniofacial malformation, tumor of the airway, subglottic stenosis, bilateral vocal fold paralysis, airway intubation trauma, laryngeal anomalies, and tracheomalacia. The prolonged ventilation group consisted of pulmonary insufficiency, cardiac malformation, neurological disorders and myopathies, and central hypoventilation.

The complications were divided into perioperative (until 48 h after the operation) and postoperative, and further subdivided into serious, intermediate and minor complications as described by Gysin et al. [4]: serious perioperative complications (death, cardiopulmonary arrest, pneumothorax, pneumomediastinum), intermediate perioperative complications (desaturation/hypotension, post-tracheal wall lesion, cannula misplacement, aspiration) minor perioperative complications (hemorrhage, difficult tube placement, false passage, subcutaneous emphysema), serious postoperative complications (death, tracheooesophageal fistula, mediastinitis, sepsis, intratracheal hemorrhage, pneumothorax, cannula obstruction, cannula displacement, tracheal stenosis) intermediate postoperative complications (pneumonia, atelectasis, aspiration, difficult cannula change), and minor postoperative complications (external hemorrhage, wound infection, tracheitis). In addition long-term postoperative complications included tracheal stenosis, tracheal cartilage lesion, and delayed cutaneous closure. Furthermore, we looked at the number of patients who underwent a surgical closure of a persistent tracheocutaneous fistula after decannulation and the complications related to this procedure.

The second part of the study consisted of comparing our results with data from an earlier study done at the same institution by Simma et al. [3], reviewing the patients with tracheotomies treated between 1979 and 1989 (group A). A

longitudinal analysis assessed differences in indications for tracheotomy, age at the time of operation, duration of cannulation, and mortality. In order to compare similar time frame durations, the recent group was subdivided into two groups: 1990–1999 (group B) and 2000–2009 (group C).

All statistical analyses were done using the commercially available statistical package IBM SPSS Statistics v20. Most statistics are descriptive. Difference between means was evaluated with ANOVA statistics.

2. Result

2.1. Patients and indications

Of the 119 patients included, 70 (59%) were male and 49 (41%) were female. Airway obstruction was the most common indication for tracheotomy and accounted for 83 of the patients (70%), while prolonged ventilation was the indication for tracheotomy for the remaining 36 patients (30%). These categories were again split into subgroups as shown in Table 1. The largest subgroup consists of patients with a craniofacial malformation ($n=24$; 20%). The airway obstruction in these patients was mostly located at the level of the oropharynx. However, in some cases there was additional obstruction due to choanal atresia or laryngeal pathology. The most common craniofacial malformation syndrome in our population was CHARGE syndrome, which was found in 6 patients. Of the 17 patients (14%) patients with airway obstruction due to a tumor, 6 had a subglottic hemangioma, 4 a lymphatic malformation and 3 an epipharyngeal tumor. Subglottic stenosis, 9 acquired and 5 congenital, required tracheostomy in 14 patients (12%). No acquired subglottic stenosis occurred within the last 10 years. Bilateral vocal cord palsy ($n=11$; 9%) was idiopathic in 7, due to Arnold-Chiari malformation in 3 and due to a brain tumor in 1 patient. Congenital laryngeal obstruction (not counting the patients with craniofacial malformation and subglottic stenosis) was present in 4 patients (3.4%), 2 of which had severe laryngomalacia, latter found to be associated with a syndromic malformation (Costello syndrome and Smith–Magenis syndrome). In our series, no tracheotomy was performed for upper respiratory tract infection.

The largest subgroups of the patients with prolonged ventilator dependence were pulmonary insufficiency ($n=13$; 11%) and cardiac malformation ($n=9$; 8%). Neuromyopathies resulting in diaphragm muscle paresis were encountered in 8 patients (7%). Five of the 6 (5%) patients with central hypoventilation had Ondine's curse.

Age at the time of tracheotomy ranged from 0 days to 19 years, mean age 2.2±4.5 years (range 0–19 years). At the time of tracheotomy, 70% of the children were under 1 year and 78% under 3 years of age. Only three patients were older than 16 years. Of these patients operated on under the age of 3 years 43% were prematurely born. Age at the time of operation was statistically different depending of the indication ($p<.001$) as shown in Table 1.

2.2. Complications and follow-up

Follow-up was complete in 109 patients (92%). In those patients mean follow-up was 5.6 years (median 3.9 years) with a maximum of 18.3 years. Only the patients with complete follow-up were included into the analysis of decannulation and its related procedures, morbidity and mortality. Of the 10 patients, who had incomplete follow-up, 8 live abroad and 2 were lost for unknown reasons.

There was no perioperative complication. All but one tracheotomy were elective and performed in the operating room on intubated patients. One intervention was an emergency procedure in a 7-year-old patient with a Crouzon syndrome, who could not be intubated for a scheduled

Table 1 Indications.

	n	%	Age (years)	Decannulation	Cannulation duration (months)
Airway obstruction	83	70	1.3±2.8	74%	22±2.8
Craniofacial malformation	24	20.2	1.6±0.7	57%	27±8
Tumors of the airway	17	14.3	1.6±0.8	75%	24±4
Subglottic stenosis	14	11.8	1.6±0.8	92%	13±4
Bilateral vocal fold paralysis	11	9.2	0.9±0.9	90%	26±8.4
Airway intubation trauma	9	7.6	0.8±0.4	86%	8.3±3.8
Laryngeal anomalies	4	3.4	0.0±0.0	33%	19±4
Tracheomalacia	4	3.4	0.0±0.0	66%	38±2
Prolonged ventilation	36	30	4.3±6.7	52%	7.6±2.7
Pulmonary insufficiency	13	11	6.8±2.1	50%	5.5±2.4
Cardiac malformation	9	7.6	3.6±2.3	67%	6.7±2.7
Neurogical disorder/myopathy	8	6.7	3.4±2.3	25%	2.0±1.0
Central hypoventilation	6	5	1.2±1.2	75%	14.3±11.9

n: number of patients; %: percentage of patients; Average age: mean age±standard deviation in years; Cannulation duration: mean duration until decannulation±standard deviation in months.

operation. This patient was decannulated within a few days and did not suffer from any long-term complications.

Serious postoperative complications occurred in 25 patients (23%) as summarized in Table 2. Nine of them encountered several complications, bringing the number of serious and intermediate complications to 39. Besides 20 tube displacements and 15 obstructions, difficult cannula changes occurred three times and there was 1 tracheal necrosis resulting from the use of a too large cannula because of ventilation problems. There was no major bleeding. Six of these complications occurred within 1 month after tracheotomy.

Minor postoperative complications were bleeding and granuloma of the stoma. There were 35 stoma granulomas in 24 patients (22%), which were all removed, in 7 of them more than once. Two minor bleedings were observed. One patient suffered from an open skin lesion due to a too tight tracheotomy tie, and had to be closed surgically.

Table 2 Complications.

	Complications	Number of patients	Percentage of patients
Perioperative complications	0	0	0
Postoperative complications	77	47	43
- Serious	36	22	20
Death	1	1	1
Cannula displacement	20	14	13
Canula obstruction	15	11	10
Difficult tube change	3	3	3
Tracheal necrosis	1	1	1
Tracheo-oesophageal fistula	0		
Mediastinitis/ Sepsis	0		
Intratracheal hemorrhage	0		
Pneumothorax	0		
Tracheal stenosis	0		
- Intermediate	3	3	3
Difficult tube change	3	3	3
Pneumonia	0		
Atelectasis	0		
Aspiration	0		
- Minor	38	27	25
Tracheal granuloma	35	24	22
Minor external bleeding	2	2	2
Neck wound from tracheotomy ties	1	1	1
Tracheitis	0		

In 9 patients (8%) airway surgery was performed, laryngotracheoplasty in 7 patients suffering from either subglottic stenosis or bilateral vocal cord palsy. Five of these patients were successfully decannulated within 4 months after surgery. One child was decannulated after 17 months and 1 patient died 2 months after surgery because of tube displacement at home. One arytenoidectomy was unsuccessfully performed in a child with bilateral vocal cord palsy. Despite revision surgery decannulation was only possible after 7.7 years. Epiglottopexy was performed in two children with severe laryngomalacia, who happened later to have a syndrome. Decannulation in those patients was then possible more than 1 year after the procedure.

Twenty-five children (23%) died during follow-up, six of them after decannulation. Median age at the time of death was 4.3±6.7 years (range: 0–20 years). Overall mortality for patients with prolonged ventilator dependence was 38% compared to 13% in patients with airway obstruction. Only one death was related to tracheotomy due to tube displacement in 1991. Mortality due to tracheotomy was therefore 0.9%.

2.3. Decannulation

The usual procedure before decannulation included a rigid laryngotracheobronchoscopy to rule out any granuloma or other relevant airway obstruction and downsizing of the tracheostomy tube. The cannula was plugged in an inpatient setting and, if well tolerated, the patient was decannulated after 24 h. Discharge was scheduled at least 48 h after decannulation, depending on the patient's condition. Counting all 109 patients, the mean cannulation time was 26± 18 months. Follow-up included 186 cannulation-years. Successful decannulation was performed in 71 patients (60%) with an average time lapse of 28±18 months after tracheotomy. The decannulation rate in patients with airway obstruction was 74% compared to 52% for the patients in the prolonged ventilation group (Table 1), with a statistically significant difference ($p<0.05$). Nineteen patients (17%) died with the tracheostomy tube in place, on average 13 months after surgery. Two-thirds of these deceased patients had a tracheotomy for prolonged ventilation. Eighteen patients (17%) were still depended on tracheotomy at the end of the study. Median cannulation time in these patients was 29 months. Statistically significant differences were observed between the two groups of indications regarding cannulation time ($p<.05$).

A persistent tracheocutaneous fistula was observed in 27 (38%) patients after decannulation, and required surgery for closure. In most (26/27) cases, the tracheotomy was in place for more than 6 months. A significant suprastomal collapse requiring surgical treatment was present in only one patient.

Thirty percent of children who had a tracheotomy for more than 6 months had a tracheocutaneous fistula. Two

patients suffered from pneumothorax after closure of the fistula. In 5 patients (5%) repeated tracheotomy had to be performed after decannulation, in 3 patients because of recurrent upper airway obstruction, and in 2 because of difficulties with intubation for elective surgery.

2.4. Longitudinal analysis

To investigate changes in indications or complication rates over time, we divided our study population in two groups: group B (patients operated on from 1990 to 1999) and group C (patients operated on from 2000 to 2009). The results of the two groups were compared with the results of Simma et al. [3], who conducted a study including all patients who underwent a tracheotomy at the University Children's Hospital Zurich from 1979 to 1989 (group A). In order to compare the results, we had to adjust our indication groups to the ones used by Simma et al. [3]. All patients with a craniofacial malformation, a subglottic stenosis, a laryngeal malformation and a tracheal obstruction were united in to one subgroup, named congenital airway malformation. Table 3 shows the changes in indications, age at operation, decannulation rate, complications and mortality. Complication rates were calculated by number of patients affected and not by actual number of complications, since these are the results provided by Simma et al. [3]. Serious complication decreased significantly over time ($p < 0.05$).

3. Discussion

Our study shows a growing incidence of tracheotomies performed for prolonged ventilation. Other authors have also reported such a trend [5]. As a result of the continuous improvement and development of neonatal and pediatric intensive care management, more pediatric patients with complex medical conditions survive, which explains the relative increase in patients with prolonged ventilator dependence. On the other hand, other indications have decreased or disappeared. In our study, no tracheotomy was performed for an upper airway infection and more specifically epiglottitis, which is probably related to the widespread use of the *H. influenzae* type B vaccination [6]. Finally, since the improvement of the endotracheal tubes material, patients can be intubated for a longer period of time without encountering laryngotracheal complications. Walner et al. [7] stated that the number of acquired subglottic stenosis has dropped considerably since the 1990s, due to less traumatic endotracheal tubes. As a result, intubation is the therapy of choice for children with acute airway obstruction, for example due to infection, and not tracheotomy anymore [8]. Improved surgical techniques allow for mostly avoiding tracheotomy in laryngomalacia and recurrent respiratory papilloma as well as in some cases of subglottic stenosis. In the future, further decrease of the number of tracheotomies performed in patients with hemangioma should be observed since propranolol might

Table 3 Longitudinal comparison.

Indications	Group A 1979–1989 ($n=108$)		Group B 1990–1999 ($n=75$)		Group C 2000–2009 ($n=44$)	
	n	%	*n*	%	*n*	%
Airway obstruction	97	89	54	72	29	66
Congenital airway malformation	24	22	30	40	16	36.5
Tumors of the airway	12	11	8	11	9	20.5
Bilateral vocal fold paralysis	24	22	9	12	2	4.5
Airway intubation trauma	34	31	7	9	2	4.5
Croup	3	3	0	0	0	0
Prolonged ventilation	11	11	21	28	15	34
Pulmonary insufficiency	5	5	7	9.3	6	14
Cardiac malformation	0	0	6	8	3	7
Neurogical disorder/myopathy	2	2	3	4	5	11
Central hypoventilation	4	4	5	6.7	1	2

	Group A	Group B	Group C
Median age at tracheotomy (years)	0.6	0.3	0.25
Age at operation <1 year (%)	59	69	70
Decannulation rate (%)	79	84	40
Serious complications (% of patients)	27	24	15
Overall mortality (%)	7	17	27
Mortality due to tracheotomy (%)	0	1.3	0

n: number of patients; %: percentage of patients.

be an efficient therapy [9]. This shift of the indications is also observed in our longitudinal analysis with the study conducted at the University Children's Hospital Zurich from 1979 to 1989. We observe the same increase of indications for prolonged ventilation (34% in group C versus 11% in group A), which is counterbalanced with a decrease of indications for upper airway obstruction (89% in group A versus 66% in group C). Furthermore, the absolute number of tracheotomies performed in our institution has decreased. From 1990 to 2009, 119 tracheotomies were done, whereas 108 tracheotomies were performed between 1979 and 1989. This decline in number of tracheotomies has also been reported by others [2].

Our data show a correlation between indication, age at the time of tracheotomy and cannulation time, which has been stated by other authors [6,8,10,11]. The relation between these parameters is illustrated in Tables 1 and 3 explaining the results found in our longitudinal comparison. The percentage of patients who were operated on under the age of 1 year is higher in groups B and C than in group A. Cannulation time and decannulation rate cannot be compared as easily and changes over time could not be evaluated, partly because calculation of cannulation time and decannulation rate are affected by the mortality rate. Our results showed that most patients who died before decannulation, with a median time after tracheotomy of 3 months. As a consequence higher mortality leads to lower cannulation time and a lower decannulation rate [2,5].

The overall mortality has increased significantly over years, as shown in Table 3. Simma et al. [3] reported 7% mortality while our results were 17% for group B and 27% for group C. Fortunately tracheotomy-related mortality was constantly low with only one case of death in group B, which is similar to the tracheotomy-related mortality found in the literature [12]. Again, these results reflect the increased number of complex chronically ill patients having a tracheotomy.

Our study, like all the studies about pediatric tracheotomies, was retrospective, and therefore there are some limitations regarding the results. Interpreting and comparing complication rates to the literature seem very difficult. Different authors have defined complications differently and the way complication rates are calculated varies. A distinction between serious and minor complications is often made, but not uniformly. Some studies look at the number of patients affected by complications, and others list the actual number of complications. Moreover, the time of follow-up varies and one can assume that complications are less extensively reported once the patient is discharged from the hospital.

The results of our longitudinal comparison show lower complication rates over time. Since the average duration of follow-up is not specified in the publication of Simma et al. [3] only groups B and C could be compared. We looked at the number of complications per cannula-years. A decrease of the complication rate could be confirmed with 0.20 complications per cannula-year in group B compared to 0.13 in group C. The reduction of the number of complications in children with tracheotomy might reflect the improved awareness of the caregivers regarding the potential risks, the improved postoperative care, and the training of the parents before going home.

4. Conclusion

A shift in the indications of pediatric tracheostomy, with an increasing number of procedures performed for prolonged ventilation, was found within the last 30 years. As a result, the overall mortality in this complex chronically ill population becomes higher. The tracheotomy-related mortality, while still present, remains low at 0.9%. Tracheotomy remains a valid and safe option for pediatric patients.

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