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Research Article

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Pediatric Tracheostomy: A retrospective study focused on patient's characteristics and outcomes

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ABSTRACT

Objective: *To assess the patient characteristics, indications, additional interventions, and outcomes associated with surgical tracheostomy in children managed multidisciplinary pediatric and neonatal intensive care unit (PICU, NICU) following for 3 years.*

Methods: *We performed a retrospective, descriptive study within 106 pediatric tracheostomy procedures (TP) in a tertiary pediatric referral center. Inclusion criteria were age range 0-17 years and elective TPs performed by pediatric surgeons between January 2018 and January 2021. The patients existing tracheostomy or undergoing emergency TPs were excluded. The medical records and follow-up findings of pediatric patients with TP were retrospectively analyzed. The children's characteristics, indications and methods of tracheostomy, additional interventions, complications, and outcomes were recorded.*

Results: *Eighty-four children (45 female, 39 male) met inclusion criteria with a median age of 3.59 years (10 days–17 years). A tracheostomy was performed to address the complications arising from prolonged mechanical ventilation in 74 children (88%) or upper airway obstruction in 10 children (12%). All interventions were performed under general anesthesia in the operating theatre. The mean length of stay (LOS) was 35.06 (13–74 days) days. There were 31 (37%) anti-reflux and gastrostomy procedures performed as an additional intervention in cases with a tracheostomy. Early complications (11%) were noted in nine patients and included hemorrhage (n:3), accidental decannulation (n:4), and pneumothorax (n:2). Delayed complications (4%) included granulation tissue (n:1) and stenosis of tracheotomy (n:2). Fifteen patients (18%) died within an average of 33 days (2–76 days) after the tracheostomy procedure due to underlying diseases. Four patients were decannulated until now.*

Conclusion: *The under 1-year old patients predominated our series, and prolonged ventilation dependency accounted for the largest number of indications for tracheostomy, followed by airway obstruction causes. The pediatric tracheostomy is a safe and effective procedure that has a significant improvement in airway symptoms, a marked reduction in the LOS, and a low complication rate in all age groups.*

Keywords: *Tracheostomy, pediatric patients, intubation, tracheostomy cannula*

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Introduction

Ensuring continuity of the airway with an incision made in the trachea dates back to thousands of years before endotracheal intubation [1]. Caron had performed the first tracheostomy reported in children in 1766 to remove a bean from the airway of a 7-year-old child [1, 2]. Trousseau routinely used it in 1833 in patients suffering from severe respiratory distress due to pertussis [2]. Today, performing the tracheotomy procedure (TP) with techniques and instruments defined by Chevalier Jackson in 1923 is still acceptable[3,4]. Minimally invasive procedures have also been developed, such as bedside percutaneous dilatational tracheotomy (PT), which is more commonly used in adult patients[4]. Tracheostomy has been increasingly used in the last decade in pediatric patients who were unable to breathe spontaneously, ventilator-dependent, and who usually had underlying neuromuscular disorders and chronic diseases[3]. Developments in neonatal and pediatric intensive care, advancements in pediatric surgery, and multidisciplinary treatment of complex diseases have led to an increased number of ventilator-dependent patients[3-5]. Thus, tracheotomy has been increasingly used in the last decade in such patients; who were unable to breathe spontaneously, ventilator-dependent, and usually had underlying neuromuscular and chronic disorders [4]. In these conditions, tracheostomy is a life-saving surgical intervention, with significant morbidity and mortality rate [3-5]. However, the studies investigating the timing, the indications, patient's characteristics, and outcomes of pediatric tracheostomy are limited in the literature. This study aimed to describe patients' characteristics, primary indications, methods, and outcomes of pediatric tracheostomy in light of the relevant literature

Methods

Study population

After the protocol was approved by the Ethics Committee for Clinical Research in our institute (*2011 KAEK-25 2021/01-15*), the study was performed in line with the principles of the Helsinki Declaration. Pediatric patients who underwent TPs performed by three pediatric surgeons from January 2018 to March 2021 were included in this retrospective study. Children who underwent an emergency tracheostomy or had incomplete medical records were excluded. Electronic medical records of pediatric patients were retrospectively reviewed.

Demographic characteristics, diagnosis, comorbidities, indications, duration of intubation, concomitant procedures, duration of hospitalization, complications, and patient outcomes were recorded.

Operation technique

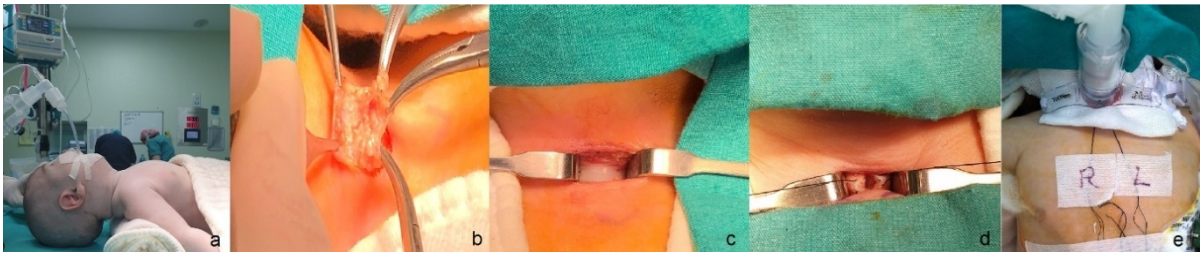
The procedure was performed after obtaining written consent from each parent. Under general anesthesia, the patient was positioned with a hyperextended neck utilizing a shoulder roll. (Figure 1a). After local anesthetic infiltration, a midline transverse incision was made below the cricoid cartilage and 1.5–2 cm above the jugular notch. Following the skin incision, the subcutaneous fat was removed to clear visualization, and lack redundant tissue in the tracheotomy tract allowing cannulation easier (Figure 1b). Next, the strap muscles were divided in the midline laterally. The midline dissection was performed, and optimal exposure was achieved by the traction of opposing Farabeuf retractors after opening each layer (Figure 1c). During the procedure, care was taken to apply equal force to the retractors and palpate the trachea between the retractors to observe the trachea's centralized location. The third and fourth tracheal rings were identified, and two non-absorbable stay sutures were placed paramedian at the intended incision. Following the vertical tracheal incision, the intubation tube was retracted, and the cannula was inserted into the trachea (Figure 1d & Figure 1e). Patients were transferred to the NICU or PICU postoperatively.

Early postoperative care focused on keeping the wound clean and free of accumulating secretions both from the soft tissue wound and from within the airway. Suctioning frequency was minimized to limit the trauma on the airway. The surgical site was inspected concerning hemorrhage for 24 hours, the sutures were removed on the 7^{th}-10^{th} days. As the changing tracheostomy tubes before the stoma matures are more likely to be misplaced in the soft tissue, the tracheostomy tubes were changed at least after the first week. Following surgery, the patients' relatives were trained in tracheostomy care, home ventilator use, and informed about possible emergencies.

Results

All TPs were performed by pediatric surgeons under general anesthesia. Patients were transferred to the NICU or PICU postoperatively. In total, 106 patients' files were evaluated. Eighty-four patients TPs were assessed, out of whom 45 patients were female and 39 were male. The median age of the patients was 3.59 years, ranging between 10 days and 17 years. The median age of the patients was 3.59 years, ranging between 10 days and 17 years. The age distribution of patients was as follows: 6 patients- newborn period (0–1 month), 35 patients (1 month-12 month), 12 patients- infancy (12–24 months), 10 patients- preschool age (2–5 years), eight patients- school age (5–10 years), and 13 patients adolescents. The patients' demographic information was presented in Table 1, and the age distribution was shown in Figure 2. The mean duration of intubation before the surgical TP was 37.64 days (10–90 days) in all patients (Table 1).

Figure 1a, b, c, d, e: 1a. After administering general anesthesia lying in the supine position, hyperextension of the neck was provided by a rolled towel placed under the patient's shoulders;



1b. After the skin incision, the subcutaneous fatty tissues were dissected and excised; 1c. Midline dissection was performed, and optimal exposure was achieved by opposing Farabeuf retractors after opening each fascia; 1d&1e. Two silk sutures were placed as sling sutures in the vertical plane. Following the midline tracheal incision, the intubation tube was retracted, and the cannula was inserted into the trachea.

Table 1. The demographic characteristics of patients with tracheotomy

Patients characteristics		
Age *(mean)*		*3,59 years*
≤1 year (0-12 months) (n)	*44*	
1 year ≤ (12 -204 months) (n)	*40*	
Gender (Female / Male)		*45/39*
Duration of intubation *(Mean)*		*37.64*
Length of stay after tracheotomy *(Mean)*		*35 (13-74) days*

The indications for TP fell into two groups: airway obstruction and respiratory failure requiring prolonged mechanical ventilation support (Table 2). The underlying diseases of prolonged ventilation were including neurological disorders (n:51), metabolic disease (n:11), muscular dystrophy (n:10), and posttraumatic ventilator dependence for two patients (Table 2).

Six of the 10 patients with airway obstruction were tracheotomized after detected laryngomalacia. The remaining four patients underwent TP due to chronic congenital anomalies caused by airway obstruction. They had been diagnosed with achondroplasia, microcephalia, osteogenesis imperfecta, and Pierre Robin syndrome (Table 2). On average, the patients were discharged on the 35^{th} postoperative day (range, 13^{th}–74^{th} day).

Thirty-one patients with an indication of tracheostomy also had gastroesophageal reflux disease (GERD) unresponsive to medical treatment. In addition, these patients had growth retardation accompanied by difficulty swallowing and feeding, recurrent pneumonia episodes, and life-threatening respiratory system complications. Therefore, laparoscopic Nissen fundoplication (LNF) and gastrostomy procedures were simultaneously performed in 31 patients, most of whom with neurological disorder (74%), as a concomitant procedure with the consensus of a medical team, involving a pediatrician, neonatologist, gastroenterologist, and pediatric surgeon (Table 2).

The early complications (11%) were minor hemorrhage in three patients, pneumothorax in two patients, and accidental decannulation, which required general anesthesia for recannulation, in four patients. In the late period (4%), excessive granuloma formation requiring excision occurred in one patient, and in two patients, the cannula could not be changed because of ostium stenosis, necessitating dilation under general anesthesia (Table 3). Four patients have been decannulated to date. Fifteen deaths occurred (18%) within an average of 33 days of the TP death reason of children was due to causes unrelated to TP. The surviving 69 patients have been followed up for an average of 16 months (range, 0–36 months) postoperatively.

Discussion

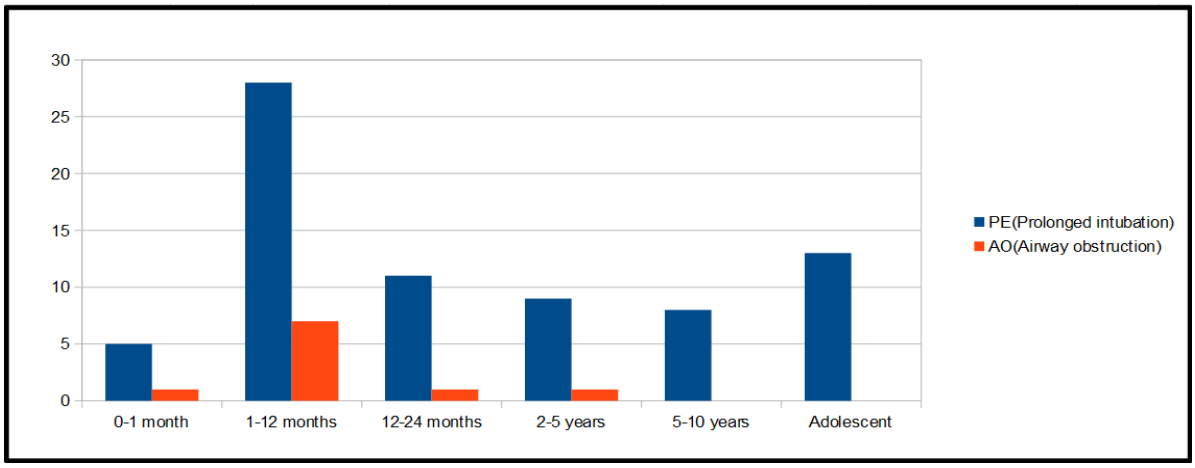
Pediatric critical care medicine has increasingly focused on critically ill children with tracheotomies and long-term ventilation to manage their compromised airways and ventilation process. In addition, technically advanced tracheostomy care has enabled mechanical ventilation at home for pediatric patients, reducing the duration of intensive care units and hospital stays [3,6,7]. In our retrospective evaluation of pediatric patients with elective tracheostomy in three years, we determined that our patients had benefited from this approach, encouraging us to continue using it, even though the procedure was not risk-free, and various early and late complications, including mortality, had occurred throughout the study period.

The age distribution of pediatric TP in our series was mostly parallel with the published studies in the literature. A study on 206 children who had undergone an elective tracheostomy between one year reported that 34.0% were newborns and 54.4% were prematurely born [8].

The rate of patients below one year of age undergoing tracheotomy was 48% by Donnelly et al. [9] and 55% by Carron et al. [10]. However, they noted that the tracheostomy procedure under one year of age is a difficult-to-perform technique with a high complication rate [9-11]. In our study, while 52% of patients are under one year of age, the rate of newborn's TP is 15%. Although it is technically challenging to perform a tracheostomy in this age group, safe surgery can be achieved when attention is paid to anatomical features such as the trachea being more superiorly located, smaller in diameter, shorter, and less stabilized and the carina being located higher.

The indications for tracheostomy in children and their management have changed significantly in the last 50 years [3,10]. Before the widespread application of vaccination in children, viral and bacterial infections such as croup, diphtheria, and epiglottitis were common tracheostomy indications. In contrast, today, tracheostomy indications include congenital/acquired upper airway tract anomalies, and dependence on prolonged mechanical ventilation due to chronic diseases [3,12]. In a co-analysis, the literature of 36 pediatric hospitals evaluating 917 children undergoing tracheostomy, the frequency of underlying comorbid conditions, chronic lung disease (56%), neurological disorders (48%), and upper airway anomalies have been reported as 47% [13].

Figure 2. The age distrubution of patients



Newborn period (0–1 month), under 1year (1-12 months), infancy (12–24 months), preschool age (2–5 years), school age (5–10 years), and adolescents.

Table 2. Data on tracheostomy procedures regarding the indication, diagnosis, and additional interventions in 84 patients

Indications		Number of patients (n)	LNF&Gastrostomy (n)
Prolonged Intubation		74	31
Neurological disorder		51	23
	Cerebral palsy	35	18
	Epilepsy	5	3
	HIE	3	-
	Tuberculous meningitis	1	-
	Post CPR	6	2
	Ensephalosele	1	-
Metabolic disease		11	2
	Neurometabolic syndrome	8	2
	Pompe disease	1	-
	Tay -Sachs disease	1	-
	Gangliosidosis GM1	1	-
Muscular Distrophy		10	4
	Muscular Leucodistrophy	6	
	Spinal Muscular Distrophy	4	4
Post-trauma		2	-
Air-way obstruction		10	2
Congenital anomalies			
	Laryngomalacia	6	1
	Acondroplasia	1	-
	Osteo genesis imperfecta	1	-
	Microcephaly	1	1
	Pierre robin syndrome	1	-

LNF: Laparoscopic Nissen fundoplication; CPR: Cardiopulmonary resuscitation; HIE: hypoxic ischemic encephalopathy

Besides, in the study by Carron et al., TP was primarily performed due to prolonged intubation (53%), based on neurological diseases, and upper airway obstruction (19%), including craniofacial anomalies (13%), trauma (7%) and paralysis (7%) [10]. Also in our series, the most indication for TP was prolonged intubation, resulting from neurological disorders (60.7%), metabolic disease (13.09%), muscular dystrophy (12%), and trauma (2.4%).

Neurological disorders such as hypoxic-ischemic encephalopathy (HIE), cerebral palsy (CP), meningitis, and neuro-motor developmental defects are accompanied by severe respiratory distress [14].

The primary causes of aspiration pneumonia in these patients are related to feeding and swallowing disorders and gastro-oesophageal reflux (GER). Patients with neurological disabilities and symptoms of GERD resistant to medical treatment are treated by Nissen fundoplication [14,15]. Feeding by nasogastric tube or gastrostomy is widely used for neurological swallowing disorders and persistent respiratory symptoms [16-

[18]. These patients should be managed by a multidisciplinary setting of pediatricians, pulmonologists, and surgeons. A reasonable approach to tackle this issue could be to perform Nissen fundoplication, gastrostomy, and tracheostomy (*combined*) procedures simultaneously for patients depending on

Table 3. Complications of the tracheotomy procedure in 84 pediatric patients

Complications	The number of patients (n, %)
Early Complications	**9, (11%)**
Accidental Decannulation	4
Minor Hemorrhage	3
Pneumothorax	2
Late Complications	**3, (4%)**
Granulation tissue	1
Stenosis of tracheostomy	2
Total	**12, (14%)**

mechanical ventilation and requiring anti-reflux surgery. Shima et al. reported the rate of fundoplication and tracheostomy as 42% in a series of 14 patients with severe neurological disability [16]. Barnhart et al. reported that they had performed fundoplication, gastrostomy, and tracheostomy in 20.8% of the cases during five years [17]. In a report on 23 children with severe neuro-motor damage, Yoon et al. reported that concurrent tracheostomy and anti-reflux procedures had been performed at a rate of 17.4% [18]. This ratio was 32.46% in our study, and we believe that performing a combined procedure without additional anesthesia risk is more effective for children, considering the patients' poor status.

Although there is a consensus that tracheostomy should be performed at 1 or 2 weeks of ventilation for adult patients, there is no clear consensus on the duration a child should remain intubated before performing TP [3,7,19]. Therefore, the evaluation is made on an individual basis. In a review on tracheostomy in infants and children by Watters, it was stated that the timing of tracheotomy and the number of extubation trials before tracheostomy varied with stressed sites [3]. Also, in a co-report of different intensive ICUs in the United States, the duration before tracheostomy was performed ranged from 4.3 to 30.4 days, with an average of 14.4 days [19-21]. The patients' mean ventilation duration before tracheotomy was 37.64 (5–90) days in our series. While this period was shorter in patients with upper airway obstruction, it was longer in patients who had undergone a tracheostomy due to neurological diseases and prolonged laryngeal intubation. Our results indicated a longer duration than previously reported in the literature. The families' difficulty accepting this situation and giving consent, and the delay in providing social standards for the supply of home ventilators can explain this difference.

Tracheotomy techniques in pediatric patients have changed over time. PT, recommended as a minimally invasive procedure, is a standard treatment modality in adults, while, it is still rarely used for children [22, 23]. The role of PT in children is clearly defined recently in limited reports. Gollu et al., in the most extensive series of 51 pediatric patients, emphasized the applicability of PT in children by a specially designed pediatric-sized version with sharp-tipped separating forceps [23].

In the open procedure, techniques including skin and tracheal incision specific to pediatric tracheostomy, subcutaneous tissue removal, maturation, and tracheal stay suture vary among surgeons [4,24]. Following a vertical incision through the trachea, we placed a tracheostomy cannula in the opening supported by stay sutures without removing any tissue. Although the tracheostomy technique varies between clinics, its basic principles are shared.

Anette et al. reported that 78% of patients who had undergone a tracheostomy procedure were dependent on long-term tracheotomy [4,5,25]. Consequently, the patients' caregivers should be given training on aspiration, cannula replacement, and emergency intervention after discharge. In our clinic, the patients' families with tracheotomy were trained on tracheotomy care, and brochures as guidelines were given before discharge.

Regarding pediatric tracheostomy complications, rates of approximately 77% have been reported in the literature [4,26]. They may be classified as early and late complications [4]. Early complications that develop during the surgical procedure or in the first seven days after surgery are usually due to the operation technique. Injury due to tube placement damages the surrounding tissues during the intervention, subcutaneous

emphysema, pneumothorax, pneumomediastinum; respiratory arrest development, accidental decannulation, and hemorrhage are referred to as early complications [4,26]. The pneumothorax, pneumomediastinum, or subcutaneous emphysema have been reported in approximately 3%–9% of tracheostomies [4]. In two (2,5%) patients with pneumothorax in the present series, the treatment was provided with tube thoracotomy. Also, Watters considered that minimizing pretracheal and paratracheal dissection might have prevented pneumomediastinum [4]. The issue of late complications such as mucus plug, development of granulation tissue, subglottic stenosis, tracheo-innominate arterial fistula, oesophageal fistula, and swallowing problems have critical importance as life-threatening complications [4,26]. In our study, the granulation tissue was prone to bleed and was required excision under general anesthesia. The other late-period complication was, ostium stenosis, necessitating dilation under general anesthesia.

There is a lack of consensus on the optimal decannulation protocol for children. Before decannulation, the indication for tracheostomy should be eliminated, the need for mechanical ventilation should be discontinued for at least 3–6 months, and the trachea's cross-section should expand naturally [4,5,11,27]. Moreover, comorbidities affecting the need for tracheostomy, including cardiac, pulmonary, or neurological conditions, should heal or resolve. The procedure can be implemented using different approaches; however, all approaches aim to reduce airflow through the cannula gradually [4,27]. Although decannulation's success rates varying between 67% and 94% have been presented in the literature, it was 2.6% in our series [4,16,27]. It is believed that the observed reducing rate for decannulation in the present study could be attributed to the patients' comorbid pathologies.

Studies have reported that 7%–8% of children do not survive after tracheostomy [4,13,27]. There are also studies reporting mortality rates as high as 42% [26]. However, this high mortality rate is based on the patients' comorbidities [4,26]. In the present series, the mortality rate was found as 18%. The causes of death for 15 patients were related to concomitant diseases, independent of the tracheostomy procedure. The tracheotomy-related mortality and complication rates can be reduced by training all healthcare professionals and patients' families and caregivers about tracheotomy care and emergency first response [4,26]. Based on our series data, we consider that training the parents before and after discharge periodically about tracheotomy care might have reduced the mortality rate.

The limitations of this study are that has a retrospective design with a relatively small sample size, does not have data on the long-term outcomes of the TP, and does not involve any information about the parents' attitudes as caregivers.

Conclusion

Finally, the majority of our patients were younger than 1 year old. Also, the primary indication for pediatric TP was prolonged intubation that mostly consisted of neurological disorders in our series. The tracheotomy is a highly successful survival procedure that provides significant improvement in airway symptoms for various diseases and a marked reduction in the need for ICU stay in all age groups. We also think that the TP can be performed readily and safely by experienced pediatric surgeons for congenital / acquired chronic diseases in need of a multidisciplinary approach which is crucial for the management.

Declarations

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Conflicts of interest/Competing interests: The authors declare that there is no conflict of interest.

Ethics approval: The Ethics Committee for Clinical Research in the Bursa Yuksek Ihtisas Training and Research hospital at the University of Health Sciences approved this study (2011 KAEK-25 2021/01-15).

Availability of data and material: All data of the study is available for re-assessment.

Authors' contributions: EO and MK researched literature and conceived the study. EO, FK, and MK performed the surgical procedures under the general anesthesia applied by SE. AO and IGV have managed the patients in NICU and PICU then gained the consent forms. EO, FK, SE, AO, and IGV have assessed data. EO wrote the first draft paper, then MK revised the article with the final arrangements. All authors reviewed and edited the manuscript and approved the final version of the manuscript.

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