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Tracheoplasty: Outcomes of a 10-Year Experience

Trakeoplasti: 10 Yıllık Deneyimin Sonuçları

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Tracheoplasty: Outcomes of a 10-Year Experience

ABSTRACT

Objective: Tracheal stenoses are generally classified as acquired vs. congenital, extrinsic vs. intrinsic, or short-segment vs. long-segment stenoses. Despite etiopathological differences, endoscopic, or surgical interventions are required for patients in whom conservative management proves insufficient. In this study, we aimed to share our clinical experience with patients who underwent tracheoplasty.

Material and Methods: The medical records of patients who underwent tracheoplasty in our clinic over the last 10 years were retrospectively reviewed. Demographic characteristics, surgical methods, and early, and late-term outcomes were evaluated.

Results: Between January 2013 and January 2023, 32 out of 226 patients who underwent tracheostomy in our clinic were treated with tracheoplasty. Of these patients, 17 were male, and 15 were female, with ages ranging from 3 months to 15 years. The mean duration of tracheostomy was 8 months, and the mean age at the time of tracheoplasty was 2.5 years. Endoscopic procedures were performed on 17 patients, while 21 patients underwent open surgical procedures. Five patients who did not benefit from endoscopic intervention subsequently underwent patch tracheoplasty, and one patient underwent resection-anastomosis following dilatation. Regarding open surgery, patch tracheoplasty was performed in 9 patients, slide tracheoplasty in 1, and resection-anastomosis in 11. While none of the patients required dilatation following open surgery, one patient each from the patch tracheoplasty, and resection-anastomosis groups required re-operation. The mean postoperative follow-up period was 4.5 years, and none of the patients required a tracheostomy after the procedure.

Conclusion: Although the survival of these patients has significantly improved over the last 20 years due to evolving surgical and endoscopic techniques, the high morbidity rates associated with therapeutic procedures remain above acceptable levels. Patient care is often conducted based on the historical experience and expertise of individual institutions rather than evidence-based standards. A multidisciplinary approach must be adopted to ensure the best long-term airway outcomes for the child.

Keywords: Patch, Pediatry, Sliding, Tracheoplasty.

Trakeoplasti: 10 Yıllık Deneyimin Sonuçları

ÖZ

Amaç: Trakeal stenozlar genel olarak; edinsel ve konjenital, ekstrensek ve intrensek ya da kısa segment – uzun segment stenozlar olarak ayrılmaktadır. Etyopatolojik olarak farklılıkları olsa da konservatif yaklaşımın yeterli olmadığı hastalarda, endoskopik veya cerrahi tedaviye ihtiyaç duyulmaktadır. Biz de çalışmamızda trakeoplasti yaptığımız hastalarımızdaki tecrübelerimizi paylaşmak istedik.

Gereç ve Yöntem: Son 10 yılda kliniğimizde trakeoplasti yapılan hastaların tıbbi kayıtları geriye dönük olarak incelenerek demografik özellikleri, cerrahi yöntem, erken ve geç sonuçlar değerlendirilmiştir.

Bulgular: Ocak 2013- Ocak 2023 arasında kliniğimizde trakeostomi açılan 226 hastanın 32 tanesine trakeoplasti işlemi uygulandı. 17'si erkek, 15'i kız hastanın yaşları 3 ay ile 15 yaş arasında değişmekte idi. Hastaların trakeostomili kalma süresi ortalama 8 ay, trakeoplasti yaşı ortalama 2,5 yaş olarak saptandı. Hastaların 17'sine endoskopik işlem uygulanırken, 21'ine açık cerrahi işlem uygulandı. 5 hasta endoskopik işlemden fayda görmeyip sonrasında yama trakeoplasti uygulandı, 1 hastaya ise dilatasyon sonrası rezeksiyon-anastamoz yapıldı. Açık cerrahi işlem olarak 9 hastaya yama trakeoplasti, 1 hastaya sliding trakeoplasti, 11 hastaya ise rezeksiyon-anastamoz yapıldı. Açık cerrahi sonrası hiçbir hastanın dilatasyon ihtiyacı olmazken yama trakeoplasti ve rezeksiyon-anastamoz yapılan birer hastanın re-operasyon ihtiyacı oldu. Hastaların post-op izlem süresi ortalama 4,5yıl olup, hiçbirinde işlem sonrası trakeostomi ihtiyacı olmadı.

Sonuç: Son 20 yılda gelişen cerrahi ve endoskopik teknikler sayesinde bu hastaların sağkalımı belirgin şekilde düzelse de terapötik işlemlere bağlı gelişen yüksek morbidite oranları hala kabul edilebilir düzeyin üzerindedir. Hasta bakımı kanıta dayalı standartlar yerine her kurumun geçmiş tecrübe ve uzmanlığı temelinde yürütülmektedir. Multidisipliner bir yaklaşımla çocuk için en iyi uzun dönem hava yolu sonuçlarının alınması sağlanmalıdır.

Anahtar Kelimeler: Pediatri, Sliding, Trakeoplasti, Yama.

Introduction

Tracheal stenosis is estimated to occur in approximately 1 in 65,000 live births (1). Tracheal stenoses (TS) are generally classified as acquired versus congenital, extrinsic versus intrinsic, or short-segment versus long-segment. Acquired types of pediatric tracheal stenosis include intubation trauma, and the formation of granulation tissue secondary to tracheostomy. These conditions arise when the pressure of the endotracheal tube exceeds the mean capillary pressure of the tracheal mucosa. It has been demonstrated that stenosis can develop even after as little as 36 hours of intubation (2). Today, with the improvement of intensive care conditions, the survival rates of very low birth weight infants have increased, and the care of term infants with congenital anomalies has advanced. Many of these infants require prolonged mechanical ventilation. The incidence of pediatric tracheostomy varies between 0.55% and 2.7%, while the rates of tracheal stenosis development due to prolonged intubation range from 0.6% to 21% (3).

Non-invasive methods such as spiral CT, MRI, esophagography, and virtual bronchoscopy are helpful in diagnosis. Immediately prior to surgery, flexible bronchoscopy should be performed to evaluate the degree of stenosis and segment length in detail. Medical management consists of anti-reflux therapy, treatment of infections, and chest physiotherapy. Despite etiopathological differences, endoscopic, or surgical interventions are required for patients in whom conservative management is insufficient.

Endoscopic treatments encompass laser excision, dilatation, and stent placement. In long-segment stenoses, endoscopic methods are often inadequate and require repetition, which increases the risk of potential complications. Open surgical treatments utilize patch tracheoplasty, slide tracheoplasty, and resection-anastomosis techniques. Resection can be safely performed on up to 30% of the trachea. For longer segment stenoses, slide, or patch tracheoplasty should be preferred.

The two most critical factors determining treatment, and mortality are the length of the stenotic segment, and the presence of concomitant anomalies. Since the description of patch tracheoplasty by Kimura, followed by slide tracheoplasty by Tsang and Grillo, mortality rates have decreased from 80% to 10% (4-6). However, complication rates following tracheoplasty remain above acceptable levels, with granulation tissue formation being the most common complication. Endoscopic methods yield highly successful results in managing complications occurring after open surgery. Furthermore, endoscopic techniques have been reported to be effective in recurrent cases developing re-stenosis after open tracheoplasty (7).

A retrospective study was conducted to evaluate the outcomes of children who underwent tracheoplasty due to tracheal stenosis developing after tracheostomy.

Material and Methods

The medical records of patients who underwent tracheoplasty in our clinic over the last 10 years were retrospectively reviewed to evaluate their demographic characteristics, surgical techniques, and early, and late-term outcomes.

Echocardiography was performed on all patients to identify any concomitant cardiovascular malformations. Bronchoscopy was conducted both preoperatively (Figure I), and postoperatively (Figure II) for all patients. Tracheoplasty was performed in patients presenting with stenosis that narrowed more than 50% of the tracheal lumen.

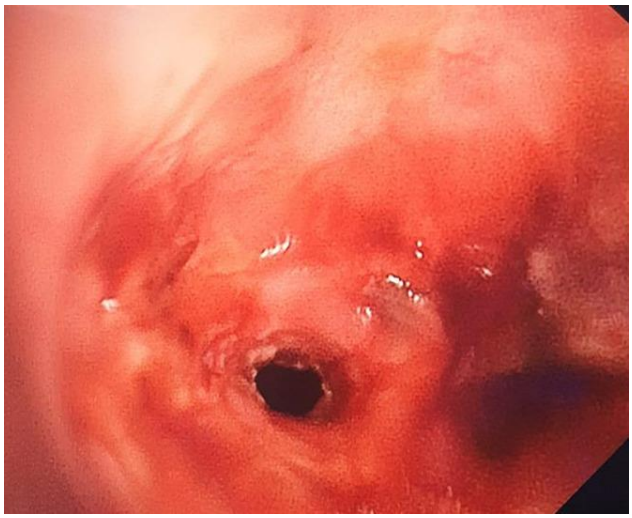

Figure I. Pre-operative Bronchoscopic View

Figure II. Post-operative Bronchoscopic View

Decannulation decisions were made on an individual basis according to each patient's clinical condition. In general, removal of the tracheostomy tube was considered when the child no longer required oxygen or ventilatory support, was able to maintain stable spontaneous breathing in room air, and had arterial blood gas values within normal limits. Before proceeding, overall clinical stability was confirmed and the airway was evaluated to ensure that adequate patency had been achieved.

Our treatment approach changed gradually over the years. In the earlier period, endoscopic dilatation was usually preferred as the initial step, and open surgical intervention was considered if the patient showed limited response to repeated dilatations or if significant airway narrowing persisted. In more recent years, however, we have tended to move toward earlier surgical reconstruction, particularly in patients with more severe stenosis or in those who did not respond adequately to endoscopic treatment. The choice of surgical technique was mainly guided by the intraoperative findings, as well as the length and severity of the stenotic segment and the overall clinical condition of the patient.

In this cohort, 9 of the 32 patients required more than one intervention during follow-up due to persistent or recurrent airway stenosis. Therefore, some patients underwent multiple procedures over time, including repeated dilatations or subsequent open surgical reconstruction. Analyses were primarily conducted on a per-patient basis, while procedural details were also presented to reflect the stepwise management approach.

When open surgical reconstruction was required, the choice of technique was mainly determined by the length of the stenotic segment. Longer segments were generally managed with patch tracheoplasty, whereas shorter, well-defined stenotic areas were treated with resection and primary anastomosis.

Statistical analyses were performed using SPSS software (version 23.0; IBM Corp., Armonk, NY, USA). Descriptive statistics were presented as number, percentage, mean, standard deviation, median, and range, as appropriate. The Mann–Whitney U test was used for comparisons between two independent groups, and the Kruskal–Wallis test was used for comparisons among more than two groups. A p-value of <0.05 was considered statistically significant.

This study was approved by the Scientific Research Ethics Committee of Karadeniz Technical University Faculty of Medicine (Approval date: 21 November 2023; Decision No: 2023/213). Due to the retrospective design of the study, the requirement for informed consent was waived.

Results

Out of 226 patients who underwent tracheostomy in our clinic over the last 10 years, tracheoplasty was performed in 32 (14.15%). Of these patients, 17 were male, and 15 were female, with ages ranging from 3 months to 15 years (mean age: 2.5 years). The mean duration of tracheostomy was 8 months (range: 1–30 months), and the median age at the time of surgery was 2.5 years.

The demographic characteristics of the participants are presented in Table 1.

Table 1. Demographic Characteristics of Participants

				n	%
Gender	Male			17	53.1
	Female			15	46.9
Tracheostomy Size (Fr)	2.50			1	3.8
	3.00			8	30.8
	3.50			8	30.8
	4.00			4	15.4
	4.50			2	7.7
	5.00			1	3.8
	5.50			1	3.8
	7.00			1	3.8
Numerical Variables	**n**	**Min.**	**Max.**	**Mean**	**SD**
1. Duration of Hospitalization (Days)	31	1.00	51.00	8.45	10.86
2. Duration of Hospitalization (Days)	15	1.00	21.00	7.93	6.17
3. Duration of Hospitalization (Days)	4	1.00	7.00	3.75	2.75
4. Duration of Hospitalization (Days)	1	1.00	1.00	1.00	-
5. Duration of Hospitalization (Days)	1	1.00	1.00	1.00	-
Age at Intubation (days)	32	1.00	5.475.00	614.00	1.181.60
Age at Tracheostomy (Days)	29	1.00	5.475.00	602.76	1.214.78
Age at Tracheoplasty (months)	32	3.00	180.00	27.83	38.45
Duration of Tracheostomy (months)	32	1.00	30.00	7.58	7.42
Follow-up Duration (Years)	32	1.00	10.00	4.28	3.26

The most common indications for tracheostomy were cerebral malformations, and Pierre-Robin syndrome, followed by patients with tracheoesophageal fistula, and Down syndrome (Table 2). Tracheostomy was performed in four patients following trauma, and in one patient after cardiac arrest during inguinal hernia surgery.

Table II. Accompanying Anomalies

Additional Anomaly	**n**
Cerebral Malformations	7
Pierre Robin Syndrome	5
Tracheoesophageal fistula/atresia	2
Down Syndrome	2
Cleft Lip and Palate	1
Sandhoff Syndrome	1
Anorectal Malformation	1
Omphalocele	1
Malrotation	1
AVSD (Atrioventricular Septal Defect)	1

Endoscopic procedures were performed on 17 patients, while 21 patients underwent open surgical intervention. Among the 17 patients treated endoscopically, granulation tissue was excised in 4 cases, and 13 were enrolled in a dilatation program. The maximum number of dilatations performed on a single patient was five. Among the 13 patients initially managed with endoscopic dilatation, 5 later required patch tracheoplasty and 1 underwent resection–anastomosis due to persistent or recurrent stenosis.

Regarding open surgery, patch tracheoplasty was performed in 9 patients, sliding tracheoplasty in 1 (Figure 3), and resection-anastomosis in 11 (Figure 4). In patients who underwent patch tracheoplasty, the right second

costal cartilage, or auricular cartilage was utilized. In the resection-anastomosis group, the stenotic segment containing granulation tissue was excised, followed by interrupted sutures using Vicryl. The laryngeal, and recurrent nerves were preserved during the procedures.

Figure III. Sliding Tracheoplasty

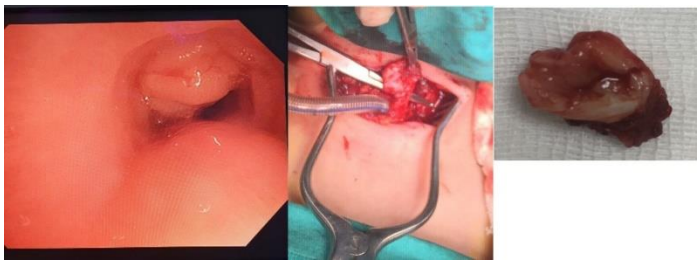

Figure IV. Resection-Anastomosis Tracheoplasty

The distribution of surgical procedure types is presented in Table 3.

Table III. Distribution of Surgical Procedure Types

		n	%
1. Surgical Procedure	Dilatation	13	40.6
	Resection-anastomosis	14	43.8
	Patch	4	12.5
	Sliding	1	3.1
2. Surgical Procedure	Dilatation	3	33.3
	Resection-anastomosis	2	22.2
	Patch	4	44.4
	Sliding	-	-
3. Surgical Procedure	Dilatation	2	50.0
	Resection-anastomosis	-	-
	Patch	2	50.0
	Sliding	-	-
4. Surgical Procedure	Dilatation	1	100
	Resection-anastomosis	-	-
	Patch	-	-
	Sliding	-	-
5. Surgical Procedure	Dilatation	1	100
	Resection-anastomosis	-	-
	Patch	-	-
	Sliding	-	-

The duration of hospital stays averaged 2 days (range:1–5 days) for patients undergoing endoscopic surgery, and 16 days (range: 5–51 days) for those undergoing open surgical procedures. This duration varied according to the specific technique: 11.4 days (range:5–21 days) for patch tracheoplasty, 14 days for sliding tracheoplasty, and 19.75 days (range: 6–51 days) for resection-anastomosis. Following open surgery, patients were monitored under intubation for 3–5 days. A comparison of the length of hospital stays according to surgical procedure types is presented in Table 4.

Table IV. Comparison of Number of Hospitalizations by Surgical Procedure Types

	1st Surgery – 1st Hospitalization			2nd Surgery – 2nd Hospitalization			3rd Surgery – 3rd Hospitalization		
	n	Mean	SD	n	Mean	SD	n	Mean	SD
Dilatation	13	2.15	0.90	3	1.67	0.58	2	1.50	0.71
Resection-anastomosis	14	14.00	14.05	2	11.00	2.83	-	-	-
Patch	3	9.33	2.08	4	14.25	6.99	2	6.00	1.41
Sliding	1	10.00	-	-	-	-	-	-	-
Test and Significance	x^2_{KW}=16.523 *p=**0.001***			F=5.377 *p=**0.046***			U=0.000 *p=0.333*		

F: Analysis of Variance (ANOVA), x^2_{KW}: Kruskall Wallis Test.

As illustrated in Table 4, the difference in the mean duration of hospital stay according to the type of surgery during the first admission was statistically significant ($p<0.05$). In the post-hoc analysis (U) conducted to determine the source of this difference, it was found that the mean hospital stay for patients undergoing dilatation was significantly lower than for those undergoing resection-anastomosis, or patch tracheoplasty. Similarly, the difference in the mean duration of hospital stay according to the surgical technique during the second admission was also statistically significant ($p<0.05$). Post-hoc analysis (LSD) revealed that the mean hospital stay for the dilatation group was lower than that of the patch tracheoplasty group. However, the difference in mean hospital stay during the third admission was not statistically significant ($p>0.05$).

No statistically significant differences were observed in mean intubation age, age at tracheostomy, age at tracheoplasty, or duration of tracheostomy according to the type of surgical procedure (p>0.05).

Five patients who did not benefit from endoscopic intervention subsequently underwent patch tracheoplasty, and one patient underwent resection-anastomosis following dilatation. While none of the patients required dilatation after open surgery, one patient each from the patch tracheoplasty, and resection-anastomosis groups required re-operation (Table 5). Re-operation was required in 41% of patients in the endoscopic procedure group, compared to 9.5% of patients in the open surgery group (p<0.05).

Table V. Recurrent Cases

Age	Gender	Diagnosis	Tracheostomy Duration	1st Surgery	2nd Surgery	3rd Surgery	4th Surgery	5th Surgery
3 months	F	Tracheomalacia	8 months	D	2 months later **Patch**			
2.5 months	M	Tracheomalacia	9 months	D	3 months later **Patch**	3 months later **Patch**		
5 years	M	Trauma	1 months	D	1 month later **D**	1.5 months later **D**		
6 years	M	Inhalation burn	1 months	D	10 months later **D**	6 months later **D**	6 months later **D**	6 months later **D**
2.5 months	F	Tracheomalacia	1 months	D	1 month later **D**	2 months later **Patch**		
21 days	M	Pierre Robin Syndrome	6 months	D	4 months later **Patch**			
15 years	M	Trauma	5 months	D	3 months later **R-A**			
20 days	M	Tracheomalacia	18 months	R-A	17 months later **R-A**			
4 years	K	Epandymoma	4 months	D	**7** months later **Patch**			

(F: Female, M: Male, D: Dilatation, R-A: Resection-anastomosis)

The mean postoperative follow-up period for the patients was 4.5 years (range:0.5–10 years), and none of the patients required a tracheostomy following the intervention. All cases achieved the ability to breathe spontaneously in room air. No cases of pulmonary infection requiring hospitalization or permanent dysphonia were observed. Although transient swallowing dysfunction for liquids was encountered in the early postoperative period, it was successfully resolved with swallowing therapy.

Discussion

Long-segment tracheal stenosis is a severe, and often life-threatening anatomical anomaly characterized by narrowing of more than 50% of the tracheal length (8,9). Surgical intervention is mandatory in cases of respiratory failure, or clinical deterioration (10). Following the first successful surgical treatment reported by Cantrell and Guild in 1964 (11), numerous surgical techniques have been described. The optimal age for surgery is considered to be between 10 and 24 months (12). In children younger than 10 months, stenosis is frequently congenital in etiology. Conversely, in older children, the tracheal stenosis tends to be longer, leading to more prolonged anastomosis procedures, and higher anastomotic tension. These factors extend the operative time, and may increase the risk of complications, and mortality. Long-segment tracheal stenosis is particularly associated with congenital heart diseases; in such cases, it is recommended that

cardiac repair be performed prior to tracheal surgery (13).

Preoperative bronchoscopy is essential to determine the degree of stenosis, and the length of the affected segment. Diagnosing preoperative tracheobronchomalacia via bronchoscopy helps predict postoperative airway obstruction, and guide ventilation strategies. Malacia may be masked by the stenosis, and surgery can exacerbate symptoms arising from malacic segments (14). Additionally, control bronchoscopy is recommended during surgery, or within the first seven postoperative days to evaluate the anastomotic line.

Surgical management options include endoscopic techniques, patch tracheoplasty, slide tracheoplasty, and resection-anastomosis. Lesions with a vertical length exceeding 1 cm are generally considered unsuitable for endoscopic management (1,15). Endoscopic methods are preferred for simple tracheal stenoses where the narrow segment is less than 1 cm, as a rescue treatment in cases of potential asphyxia, or as a bridge to definitive surgery. While congenital lesions often involve long-segment stenoses that preclude simple resection, and reconstruction, resection-anastomosis remains the gold standard for acquired stenoses, particularly post-intubation tracheal stenosis (15-19). In various studies on resection-anastomosis, mortality rates range from 0% to 16% (16,20-22), while restenosis rates can reach up to 45% (23). The primary advantage of sliding tracheoplasty is the reconstruction of the trachea using its own native tissue (24). This maintains the growth potential of the trachea by providing a stable cartilaginous wall with a normal epithelial lining. Furthermore, it provides flexibility for congenital lesions such as unilateral hypoplasia of the tracheal bronchus, or lung agenesis. Sliding tracheoplasty can expand the tracheal lumen by at least twofold (25), with reported mortality rates ranging from 0% to 25% (2,26,27). For patch tracheoplasty, the most commonly utilized materials are costal cartilage, pericardium, tracheal autografts, and tracheal allografts. Synthetic grafts are generally avoided due to high infection rates, and granulation tissue formation. Costal cartilage was the first successful graft developed for tracheoplasty and remains an advantageous material due to its ability to maintain viability without direct blood flow.

Early complications include leakage, mediastinitis, and granulation tissue formation, while stenosis is the primary concern in the long term. Other potential complications include tracheoesophageal fistula, and tracheal necrosis (3). Granulation tissue formation is among the most frequent complications (28,29), and is highly responsive to endoscopic management. Topical Mitomycin C, and steroids may be integrated into the treatment (1,30,31). The most severe complication following tracheal surgery is anastomotic dehiscence (29,32). The management of re-stenosis involves repeat dilatation, or re-operation after assessing the length of the narrowing via bronchoscopy.

In tracheal reconstruction surgeries, especially in infants, and young children, accurate, and timely diagnosis combined with meticulous postoperative care is vital for successful outcomes. Although the timing of postoperative extubation is debated, the generally accepted practice is to attempt extubation after 24–48 hours (15). Since the shortening of the trachea following reconstruction can lead to recurrent obstruction—particularly in patients with long-segment stenosis—careful surgical planning is required (24). Mortality rates in the literature are approximately 9% (15). The length of the stenotic segment is the only independent risk factor affecting postoperative complications, and mortality (33). In such medically complex cases, satisfactory results can only be achieved through the collaboration of a multidisciplinary team of specialists (34).

The relatively low rate of airway stenosis observed in our cohort compared to the rates reported in the literature may be attributed to a more proactive and aggressive management strategy. In our clinical practice, patients with suspected airway narrowing were closely

monitored and early intervention was preferred, particularly in cases showing progression or inadequate response to conservative measures. This approach may have limited the progression of stenosis and reduced the need for prolonged tracheostomy dependence. Similarly, the relatively shorter duration of tracheostomy observed in our series may reflect early decision-making for definitive airway reconstruction in selected patients, rather than prolonged conservative follow-up.

In our study, treatment success was defined as achieving adequate airway patency that allowed spontaneous breathing in room air without the need for tracheostomy.

One of the main limitations of our study is the heterogeneous nature of the patient population, both in terms of underlying etiologies and clinical characteristics. This variability may have influenced the outcomes and should be taken into account when interpreting the results, as it may limit the generalizability of our findings to more uniform patient groups.

Conclusion

Survival rates for patients with tracheal stenosis have significantly improved over the last 20 years, thanks to advancements in surgical, and endoscopic techniques. However, the high morbidity rates associated with therapeutic interventions remain above acceptable levels. Currently, patient care is often conducted based on the institutional experience, and clinical expertise of individual centers rather than standardized, evidence-based protocols. To achieve the best possible long-term airway outcomes in children, a multidisciplinary approach must be prioritized.

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