



Treatment Results and Postoperative Complications of Single-Stage Tracheal Resection in Adolescent Patients with Post-Intubation Tracheal Stenosis, Compared to Adults

Original Investigation

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Abstract

Objective: The purpose of this study was to analyze the treatment outcomes and postoperative complications of tracheal resection in patients under the age of 19 years with post-intubation tracheal stenosis, and to compare the results with those of adults.

Methods: Data were retrospectively retrieved from the medical records, including demographic characteristics, perioperative features, any postoperative complications and follow-up statuses of the patients. Treatment results and postoperative complications were compared between adolescent and adult groups.

Results: Overall, anastomotic and non-anastomotic complication rates in the adolescent group and the adult group were 40%, 40%, 10% and 63%, 44.4%, 33.3%, respectively. Overall treatment success rates based on tracheostomy tube and tracheal stent free status were 90% and 92.6% in adolescent and adults, respectively.

Conclusion: Treatment success rates and incidence of anastomotic complications were found similar in patients under the age of 19 years and adult patients who underwent single-stage tracheal resection and end to end anastomosis for treatment of post-intubation tracheal stenosis.

Keywords: General otorhinolaryngology, head and neck surgery, intubation, laryngology, pediatric otorhinolaryngology, surgery, trachea, tracheal stenosis

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Introduction

Intubation trauma with mucosal injury from endotracheal tubes or their cuffs is the most common cause of benign acquired tracheal stenosis (1-3). Endoscopic airway procedures such as excision of the granulation tissue and

balloon dilation are usually sufficient for successful results when the scar tissue is incipient and fragile at the early stage (4). Mature cicatricial stenosis can occur over time if etiological factors persist. Dilation, laser and/or tracheal stent placement are usually preferred and appropriate for the treatment of web-type short mature

cicatricial stenosis. However, long mature cicatricial or high-grade tracheal stenosis can pose a therapeutic challenge for surgeons.

Patients with long segment and/or high grade mature tracheal stenosis, or cartilaginous structural problems like tracheomalacia, may need more comprehensive open surgical interventions (4). Three types of open surgical methods, 'tracheal resection', 'slide tracheoplasty' and 'expansion tracheoplasty', have been defined for treating tracheal stenosis (1). Tracheal resection procedure is the complete excision of the stenotic segment and end-to-end anastomosis of the remaining healthy stumps of trachea as cricotracheal or tracheotracheal reconstruction. In contrast, expansion tracheoplasty increases the diameter of the tracheal airway lumen by using a graft without performing a circumferential tracheal resection (1). Slide tracheoplasty, is a surgical method that is generally preferred in the treatment of long segment congenital tracheal stenosis.

Circumferential tracheal resection with end-to-end anastomosis for the treatment of high grade mature tracheal stenosis has been frequently performed with high success rates in achieving decannulation of the adult patients with prolonged intubation (4, 5). Although surgical techniques and postoperative complications are well described in many studies, until quite recently, surgeons have been concerned about the potential adverse effects of tracheal and cricotracheal resection on upper aerodigestive tract growth process in the pediatric population (6). There are very few studies in the literature with a relatively small number of patients under the age of 19 years, in surgical outcomes and complications of tracheal resection for the treatment of acquired tracheal stenosis.

In this study we determined the overall, anastomotic and non-anastomotic postoperative complication rates, the incidence of need for adjunctive procedures after resection and treatment success rates of tracheal resection and end-to-end anastomosis in patients under the age of 19 years with post-intubation tracheal stenosis and compared the results with those of adult patients. Additionally, we did an analysis to define the predictive preoperative and perioperative factors that might be related to treatment outcomes.

Methods

This retrospective cohort study was approved by the Ethics Committee of the Bursa Uludağ University Faculty of Medicine (decision number: 2020-7/19 and date: 29.04.2020).

Study Groups

The medical records of 37 consecutive patients who were treated with single-stage circumferential tracheal resection and end-to-end anastomosis due to post-intubation tracheal

stenosis at the Otolaryngology Clinic of Bursa Uludağ University between January 2005 and December 2019 were retrospectively reviewed. Patients who underwent tracheal resection due to congenital tracheal stenosis, tracheoesophageal fistula or neoplastic tumors of trachea were excluded. Patients with laryngotracheal stenosis (with glottic involvement) that required partial cricotracheal resection with thyrotracheal anastomosis and patients with tracheal stenosis extending below the thoracic trachea that required thoracotomy were excluded as well. Patients under the age of 19 years comprised the adolescent group and those aged ≥ 19 years the adult group. Since we did not have any patients who had undergone tracheal resection due to post-intubation tracheal stenosis before the age of nine, patients were classified as the adolescent group, and not the pediatric group.

Surgical Technique

We used the surgical approach that was described by Grillo and Donahue (7). The main steps of the surgical technique have been described in detail in some previously published studies (8-10). Adult patients were extubated at the end of the surgery in the operating room if there were no comorbidities that required postoperative intensive care or mechanical ventilation. Adolescent patients, however, were followed under intubation in the intensive care unit for three postoperative days for effective neck stabilization, and chin-to-chest sutures were placed in all patients.

Study Variables

The independent variables were age, gender, presence of comorbidity, duration of intubation, presence of pre-existing tracheotomy, Cotton-Myer grading, prior treatment procedures, length of resection, type of anastomosis (cricotracheal or tracheotracheal), use of laryngeal and tracheal releasing maneuvers. Preoperative features and Cotton-Myer grading of the patients were assessed from the rigid endoscopic examination records which were performed under general anesthesia before the tracheal resection surgery.

The dependent variables were the presence of postoperative complications (anastomotic, non-anastomotic and overall) and treatment outcomes (treatment success after tracheal resection, need for adjunctive procedures, treatment success after adjunctive procedures and mortality).

Age, gender, duration of intubation, presence of preoperative tracheostomy, presence of prior treatment, Cotton-Myer grading, type of resection, length of resection, number of resected tracheal rings and use of laryngeal release at the stage of reconstruction were analyzed as predictive factors for treatment success.

Statistical Analysis

Statistical analyses were performed for comparisons of postoperative complications (anastomotic, non-anastomotic

and overall) and treatment outcomes between adolescent and adult patients. The preoperative and perioperative predictive factors potentially associated with treatment success without requiring any adjunctive procedures were analyzed by univariate analysis. Categorical variables were analyzed by Fisher's exact test and continuous variables with the Mann-Whitney U test. Commercially available software (SPSS Version 23.0, IBM, Armonk, NY) was used for the analyses and level of statistical significance was assumed as $p < 0.05$.

Results

Patient Characteristics and Preoperative Findings

A total of 37 (21 male and 16 female) patients with a mean age of 36.97 (range: 9 to 73) years were included in the study. There were 10 (27%) patients in the adolescent group and 27 (73%) patients in the adult group. Mean duration of intubation was 15.93 (range: 1 to 60) days. Thirty-one (83.8%) patients had pre-existing tracheotomy and 26 (70.3%) had prior treatment before tracheal resection. Based on the Cotton-Myer grading system, 8 (21.6%) patients were classified as grade II, 22 (59.5%) as grade III, and 7 (18.9%) patients were classified as grade IV. Mean follow-up time after surgery was 20.8 (range: 3 to 84) months.

There were no significant differences between the adolescent and adult groups in terms of gender, duration of intubation, pre-existing tracheotomy, prior treatment before tracheal resection, Cotton-Myer grading and duration of follow-up according to the statistical analysis ($p=1.000$, $p=0.302$, $p=0.653$, $p=1.000$, $p=0.906$ and $p=0.674$ respectively). Patient characteristics and preoperative findings are summarized in Table 1.

Perioperative Findings

The mean length of tracheal resection was 2.21 (range: 1 to 4.5) cm, 2.2 (range: 1 to 3.5) cm and 2.22 (range: 1 to 4.5) cm in overall, adolescent and adult groups, respectively ($p=0.933$). The mean number of tracheal rings resected during surgery was 4.51 (range: 2 to 8) in overall and five (range: 3 to 7) and 4.33 (range: 2 to 8) in the adolescent and adult groups, respectively ($p=0.229$). Laryngeal release was performed in 16 (43.2%) of the patients; namely, four (40%) and 12 (44.4%) patients in adolescent and adult groups, respectively ($p=1.000$).

Tracheotracheal anastomosis was performed in 27 (73%) patients and cricotracheal anastomosis was performed in 10 (27%) patients for reconstruction. Tracheotracheal anastomosis was performed in six (60%) patients in the adolescent group and in 21 (77.8%) patients in the adult group. Cricotracheal anastomosis was performed in four (40%) patients in the adolescent group and in six (22.2%) patients in the adult group. There were no significant differences between adolescent and adult groups in terms

Table 1. Patient characteristics and surgical features

	Adolescent group (n=10)	Adult group (n=27)	Total study group (n=37)	p-value
Age (years)				
Min	9	19	9	-
Max	18	73	73	
Mean	14.20	45.41	36.97	
SD	3.910	15.741	19.499	
Gender				
Male	6 (60%)	15 (55.6%)	21 (56.8%)	1.000*
Female	4 (40%)	12 (44.4%)	16 (43.2%)	
Duration of intubation (days)				
Min	7	1	1	
Max	35	60	60	
Mean	12.20	21.56	19.03	0.302**
SD	8.176	17.425	15.930	
Pre-existing tracheotomy	8 (80%)	23 (85.2%)	31 (83.8%)	0.653*
Prior Treatment	7 (70%)	19 (70.4%)	26 (70.3%)	1.000*
Cotton-Myer grading				
Grade 2	2 (20%)	6 (22.2%)	8 (21.6%)	
Grade 3	6 (60%)	16 (59.3%)	22 (59.5%)	0.906**
Grade 4	2 (20%)	5 (18.5%)	7 (18.9%)	
Duration of follow-up (months)				
Min	3	4	3	
Max	33	84	84	
Mean	16.90	26.222	23.70	0.674**
SD	8.647	23.474	20.839	
Length of resection (cm)				
Min	1	1	1	
Max	3.5	4.5	4.5	
Mean	2.200	2.222	2.216	0.933**
SD	0.788	0.933	0.886	
Number of resected tracheal rings				
Min	3	2	2	
Max	7	8	8	0.229**
Mean	5.00	4.33	4.51	
SD	1.414	1.797	1.710	
Laryngeal release	4 (40%)	12 (44.4%)	16 (43.2%)	1.000*
Type of anastomosis				
Tracheal	6 (60%)	21 (77.8%)	27 (73%)	0.407*
Cricotracheal	4 (40%)	6 (22.2%)	10 (27%)	

*Fisher's Exact test, **Mann-Whitney U test, Min: Minimum, Max: Maximum, SD: Standard deviation, n: Number

of the type of anastomosis ($p=0.407$). Table 1 shows the summary of perioperative findings according to patient groups.

Postoperative Complications

Postoperative complications occurred in 21 (56.8%) patients. Of these, 16 (43.2%) were anastomotic and 10 (27%) were non-anastomotic. The incidences of total complications in adolescent and adult patients were 40% (n=4) and 63% (n=17), respectively. The most frequent complications were restenosis (n=8, 21.6%), anastomotic dehiscence (n=5, 13.5%), pneumonia (n=4, 10.8%) and granulation tissue formation (n=3, 8.1%). Other complications were hematoma (n=2, 5.4%), unilateral cord vocal immobility (n=2, 5.4%), wound site infection (n=1, 2.7%) and keloid (n=1, 2.7%).

The incidences of anastomotic complications in adolescent and adult patients were 40% (n=4) and 44.4% (n=12), respectively. Restenosis was the most frequent anastomotic complication in both groups and occurred in two (20%) of the adolescent patients and six (22.2%) of the adult patients. The incidences of non-anastomotic complications in adolescent and adult patients were 10% (n=1) and 33.3% (n=9), respectively. The solely non-anastomotic complication of the one adolescent patient was cord vocal immobility. In the adult group, pneumonia (n=4, 14.8%) was the most frequent non-anastomotic complication. A summary of the postoperative complications according to patient groups is given in Table 2.

Treatment Outcomes and Mortality

The overall success rate after initial surgery was 64.9% (n=24). There were no differences between the success rates of the adolescent and the adult patients (p=0.716), and properly functioning anastomosis was achieved in six (60%) of the adolescents and 18 (66.7%) of the adults without the need for any adjunctive treatment. After the initial surgery, adjunctive procedures were performed in three (30%) adolescents and eight (29.6%) adults (p=1.000). Final treatment success, based on decannulation and tracheal stent-free status, was accomplished in 34 (91.9%) of the patients; namely, nine (90%) adolescents and 25 (92.6%) adults (p=1.000). Overall mortality rate was 5.4% (n=2): major anastomotic dehiscence occurred in one patient from each group, as a result of which both patients died from respiratory arrest before any surgical intervention could be done. Table 2 shows the summary of treatment outcomes and mortality rates.

Results of Univariate Analysis

None of the predictive factors (age, gender, duration of intubation, preoperative tracheotomy, prior treatment, Cotton-Myer grading, type of resection, length of resection, number of resected tracheal rings and laryngeal release) were related to the success of the treatment after initial surgery (p>0.05). The results of the univariate analysis are given in Table 3.

Discussion

Table 2. Postoperative complications and treatment results

	Adolescent group (n=10)	Adult group (n=27)	Total study group (n=37)	p-value
Total complications	4 (40%)	17 (63%)	21 (56.8%)	0.274*
Anastomotic complications				
Total	4 (40%)	12 (44.4%)	16 (43.2%)	1.000*
Restenosis	2 (20%)	6 (22.2%)	8 (21.6%)	1.000*
Dehiscence	1 (10%)	4 (14.8%)	5 (13.5%)	1.000*
Granulation tissue	1 (10%)	2 (7.4%)	3 (8.1%)	1.000*
Non-anastomotic complications				
Total	1 (10%)	9 (33.3%)	10 (27.0%)	0.229*
Pneumonia	None	4 (14.8%)	4 (10.8%)	
Hematoma	None	2 (7.4%)	2 (5.4%)	
Vocal cord paralysis	1 (10%)	1 (3.7%)	2 (5.4%)	
Wound site infection	None	1 (3.7%)	1 (2.7%)	
Keloid	None	1 (3.7%)	1 (2.7%)	
Successful treatment after initial surgery	6 (60%)	18 (66.7%)	24 (64.9%)	0.716*
Adjunctive procedures needed after initial surgery	3 (30%)	8 (29.6%)	11 (29.7%)	1.000*
Successful treatment after adjunctive procedures	9 (90%)	25 (92.6%)	34 (91.9%)	1.000*
With tracheotomy at last control	None	1 (3.7%)	1 (2.7%)	1.000*
Mortality	1 (10%)	1 (3.7%)	2 (5.4%)	0.473*

*Fisher's Exact test, n: Number

Table 3. Results of univariate analysis

	Successful treatment result after initial surgery		p-value
	Yes (n=24) (64.9%)	No (n=13) (35.1%)	
Age (years)			
Min	9	11	0.987***
Max	73	61	
Mean	36.75	37.38	
SD	20.659	17.952	
Adolescent group			
Yes	6 (16.2%)	4 (10.8%)	0.716*
No	18 (48.6)	9 (24.3%)	
Gender			
Male	16 (43.2%)	5 (13.5%)	0.192**
Female	8 (21.6%)	8 (21.6%)	
Duration of intubation (days)			
Min	4	1	0.236***
Max	60	58	
Mean	19.92	17.38	
SD	15.388	17.405	
Preoperative tracheotomy			
Yes	19 (51.4%)	12 (32.4%)	0.394*
No	5 (13.5%)	1 (2.7%)	
Prior treatment			
Yes	18 (48.6%)	8 (21.6%)	0.465*
No	6 (16.2%)	5 (13.5%)	
Cotton-Myer grading			
Grade 2	3	5	0.441***
Grade 3	17	5	
Grade 4	4	3	
Type of resection			
Tracheal	16 (43.2%)	11 (29.7%)	0.440*
Cricotracheal	8 (21.6%)	2 (5.4%)	
Length of resection (cm)			
Min	1	1	0.519***
Max	4.5	4	
Mean	2.292	2.077	
SD	0.954	0.759	
Number of resected tracheal rings			
Min	2	2	0.499***
Max	8	8	
Mean	4.67	4.23	
SD	1.810	1.536	
Laryngeal release			
Yes	10 (27%)	6 (16.2%)	1.000**
No	14 (37.8%)	7 (18.9%)	

*Fisher's Exact test, **Chi-square test (continuity correction), *** Mann-Whitney U test, Min: Minimum, Max: Maximum, SD: Standard deviation, n: Number

Circumferential tracheal resection and end-to-end anastomosis has been successfully described for the definitive treatment of acquired mature benign tracheal stenosis, with reports of high decannulation rates greater than 90% in adult patients (1-3, 5, 11). However, the management of pediatric airway disorders can be challenging for surgeons and major tracheal procedures are uncommon. There are very few articles in the literature that report about the treatment results and the postoperative complications of tracheal resection in pediatric patients with acquired benign tracheal stenosis (non-congenital) (8, 12, 13). To the best of our knowledge, this is the first report analyzing the incidence of anastomotic complications after single stage tracheal resection together with end-to-end anastomosis indicated for treating post-intubation tracheal stenosis in patients under the age of 19 years and adult patients comparatively.

The incidences of postoperative complications after tracheal resection and end-to-end anastomosis are reported between 5% to 46% in the literature (3, 14-16). Some authors defined the postoperative complications as anastomotic and non-anastomotic (14, 17). Anastomotic complications are generally more common and closely associated with surgical success, and rates even mortality. Formation of granulation tissue at the site of the anastomosis was the most common anastomotic complication of tracheal resection before the suture materials (used for anastomosis) were changed from non-absorbable to absorbable sutures (18, 19). Recent studies show restenosis to be more common than granulation tissue formation with reported incidences of 30%-40% (2, 8, 10, 16, 17). Anastomotic separation is rare, yet the most devastating complication following tracheal resection. Minor separation can occur in some cases and only with subcutaneous emphysema; however, can occasionally require surgical intervention as a major complication and may result in death unless the airway is immediately stabilized. The rate of anastomotic separation after tracheal resection ranges from 4% to 14% and its related mortality can reach 7.8% (14, 20). The 5.4% mortality rate we found in our study was similar to those reported in the literature. In two of our patients, progressive extensive subcutaneous emphysema in the neck and upper chest region developed and sudden respiratory distress emerged in the postoperative period (7th and 9th days). Respiratory arrest occurred within a short time and the patients expired due to major anastomotic dehiscence before any surgical intervention could be done.

Few studies in the literature report a high number of patients with anastomotic complications of tracheal resection. Wright et al. (14) reported the rate of anastomotic complications as 9% (37 separation of anastomosis, 37 restenosis and 7 granulation tissue) among 901 patients, of whom 62 were younger than 17 years of age. They indicated that age was a negative predictive factor for anastomotic separation. Bibas et al. (17) observed anastomotic complications in 20 out

of 94 adult patients (21.3%). Restenosis, granulation tissue formation and anastomotic separation in anastomotic line occurred in 15 (16%), four and one patients, respectively, in their study population. Piazza et al. (20) reported the rate of anastomotic complications as 46% (40 patients) among their 87 patients who underwent cricotracheal/tracheal resection due to benign tracheal stenosis. Anastomotic separation and restenosis occurred in seven (8%) and six (7%) of their patients, respectively. In a recent study including 166 adult patients at three different otorhinolaryngology departments, Fiz et al. (21) reported the overall surgical complication rate as 46%. Laryngeal edema requiring treatment was the most common complication seen in 10 (13.3%), followed by anastomotic separation in eight (10.8%) and granulation tissue formation in seven (9%) of their patients. In another study, Fiz et al. (13) reported the treatment results of 191 pediatric patients who underwent tracheal or laryngotracheal resections due to congenital or acquired laryngotracheal stenosis in four different hospitals. Single stage tracheal surgery was performed in 106 (55.5%) patients. The surgeons performed four different types of cricotracheal resections that were previously classified by Piazza et al. (13, 20). Type A resection was performed in eight patients, Type B in 31 patients, Type C in 113 patients and Type D resection in 39 patients. They determined the decannulation rate as 76% without the need for additional treatment and the final decannulation rate as 88%. Their mean overall complication rate was 24.1%. Laryngeal edema was the most common (8.9%) complication. Anastomotic separation, restenosis and granulation tissue formation occurred in 6.3%, 3.7% and 3.7% of their patients, respectively. Revision surgery was required in 74 patients (38.7%). Stenosis extending to 3–4 subsites of laryngotracheal unit, patients with airway comorbidities and patients with high European Laryngotracheal Society Score were described as risk factors of complications. If we compare the two studies by Fiz et al. (13, 21) the most common complication was laryngeal edema in both adult and pediatric patients. The overall complication rate was higher in adult patients (46% to 24.1%).

In our study, the incidences of overall and anastomotic complication rates after tracheal resection were comparable to those of the previous studies (40% in adolescents and 44.4% in adults). We found restenosis as the most common anastomotic complication. There were no significant differences between the adolescent and adult groups in terms of treatment success and the need for adjunctive procedures. We achieved 90% successful treatment results after tracheal resection +/- adjunctive procedures in the adolescent group with similar complication rates compared to adults.

A tension-free anastomotic line is essential for avoiding such anastomotic complications. The elasticity of the intercartilaginous ligaments is sufficient for low anastomosis tension in limited resections. Many researchers noted

that resection less than four cm was safe and adequate (9, 14, 19). If the length of the resection was more than four cm, adjunctive surgical interventions were usually needed. Laryngeal and tracheal release techniques have been used for decreasing the tension at the anastomotic site. However, excessive release procedures may prevent the elevation of the larynx during swallowing and thereby cause dysphagia and aspiration pneumonia (22). Determining the margins of a safe resection is more complicated since the total length of the trachea differs by age in pediatric patients. Previous studies recommend that short segment stenosis on less than 30% of the trachea should be safely resected in pediatric patients (23, 24). In our study, the length of the stenotic segment resected in all adolescent patients was relatively short and not more than 30% of the tracheal length. The most extensive resection was 3.5 cm in two patients aged 17 years in the adolescent group. Resections of one to two cm were performed in four patients aged under 12 years. Therefore, in our study group, laryngeal release was needed in only four patients who were older than 16 years. We did not apply any laryngeal release procedure in patients aged under 16 years.

Based on the results of previous studies, young age, diabetes mellitus, smoking, high grade stenosis, previous history of tracheal surgery, preoperative tracheostomy, laryngotracheal resection, long segment resection greater than four cm and the need for laryngeal release are defined as risk factors for the failure of treatment and/or for complications (2, 17, 25). Our study was limited by a relatively small number of patients, this small size prevented the use of multivariate analysis to define the predictive factors for treatment outcomes. However, according to the results of the univariate analysis, age, gender, duration of intubation, presence of preoperative tracheostomy, presence of initial treatment, grade of stenosis, type of resection, length of resection, number of resected tracheal rings and presence of laryngeal release were not related to treatment success.

Conclusion

The rates of anastomotic complications after tracheal resection and end-to-end anastomosis were similar between patients under the age of 19 and adult patients. Treatment success rates in adolescents were also as high as in adult patients. Basing on these results we can suggest that this surgery can be performed safely in patients aged younger than 19 years with high success rates and low complication risks.

Ethics Committee Approval: This retrospective cohort study was approved by the Ethics Committee of the Bursa Uludağ University Faculty of Medicine (decision number: 2020-7/19, date: 29.04.2020).

Informed Consent: Retrospective study.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: M.A., H.C., Concept: M.A., H.C., Design: H.C., Data Collection and/or Processing: M.A., M.F.Y., Analysis and/or Interpretation: M.A., M.F.Y., Literature Search: M.A., M.F.Y., Writing: M.A., H.C.

Conflict of Interest: The authors have no conflicts of interest to declare.

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Main Points

- Frequency of anastomotic complications after tracheal resection and end-to-end anastomosis is similar in patients under the age of 19 years and adults.
- According to the results of univariate analysis, age, gender, duration of intubation, presence of preoperative tracheostomy, presence of initial treatment, grade of stenosis, type of resection, length of resection, amount of resected tracheal rings and presence of laryngeal release are not related with treatment success.
- Treatment success rates in adolescents are also as high as in adult patients.
- Tracheal resection and end-to-end anastomosis can be performed safely in patients under the age of 19 years with high success rates and low risk of complications.

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