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ORIGINAL INVESTIGATION

Perioperative management of patients undergoing tracheal resection and reconstruction: a retrospective observational study

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Abstract
Background: Perioperative management of Tracheal Resection and Reconstruction (TRR) presents many challenges to the physicians involved in airway management. Factors related to postoperative outcomes can be identified as early as the preoperative setting and can even be linked to demographic characteristics of patients affected by tracheal stenosis. The primary aim of this study is to describe the experience of patients undergoing TRR at our hospital from an anesthesiology perspective, describing as a second aim demography, preoperative conditions, and postoperative complications.
Methods: This was a single institution retrospective review of patients who underwent TRR between 2009 and 2020. We did a post-hoc exploratory analysis to identify possible associations between perioperative complications and perioperative management.
Results: Forty-three ASA I–IV adult patients aged 18–72 years who underwent TRR were included. Prolonged intubation (72%) is the primary cause of tracheal stenosis. Intraoperative management: intravenous induction and laryngeal masks are now the most frequently used for airway management, especially in subglottic stenosis. Perioperative complications were vocal cord paralysis (25.6%), postoperative ventilatory support (20.9%), and need for surgical reintervention (20.9%). One patient (2%) died in the postoperative period due to anastomotic complication. After resection, dexmedetomidine is the preferred choice (48.8%) for sedoanalgesia in the ICU.
Conclusions: Perioperative management of TRR at our hospital has a low mortality and high morbidity rate. We did not find an association between perioperative anesthetic interventions and postoperative complications. Further studies are needed to evaluate which anesthetic interventions may be associated with better outcomes.

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Introduction

Tracheal Resection and Reconstruction (TRR) is the treatment of choice for many patients diagnosed with primary tracheal tumors and for those presenting with tracheal stenosis.[1] Sixty-five percent of tracheal stenosis cases around the world correspond to postintubation injuries, affecting women and men equally, with relevant predictors associated with complications of the tracheal anastomosis. These complications derive either from prior medical conditions (diabetes mellitus, tracheostomy before surgery), from intraoperative factors such as extended resections (≥ 4 cm), or those requiring additional laryngeal resection.[2]

Current recommendations for perioperative management of TRR are mostly grounded on clinical experience and observational studies from a surgical standpoint with little attention to perioperative anesthetic interventions.[2-7] This surgical procedure presents many challenges to the anesthesiologist managing the patient because the risk of losing the airway is lingering throughout the perioperative period. During surgical resection, the airway is shared and manipulated by the surgeon, and at the end of the intervention, extubation, and postoperative management add further challenges because some patients must remain with prolonged cervical flexion, and Valsalva maneuvers, such as coughing or nausea, must be avoided given the risk of tracheal anastomosis rupture.[1,8-10]

There are numerous descriptions about the preferred airway approach for patients scheduled for TRR. Most commonly, a small-size endotracheal tube is positioned proximal to the stenosis; however, other alternatives such as the use of Laryngeal Mask Airways (LMA) for cervical tracheal resection and reconstruction, and catheter-based high-frequency jet ventilation have also been successfully used.[11] The anesthetic technique also varies, but it is usually performed under general anesthesia with total intravenous or balanced techniques.[12] Therefore, anesthetic management can be a concealed factor concerning postoperative outcomes of patients undergoing TRR. The main objective of this study is to describe our experience in the perioperative anesthetic management of patients with tracheal stenosis undergoing TRR.

Methods

After obtaining the approval of the Ethics and Research Committee and the Department of Anesthesiology of the Hospital Universitario San Ignacio, a retrospective analysis of the medical records was performed to identify patients over 18 years of age with tracheal stenosis undergoing TRR in the past ten years (June 1, 2009, to May 31, 2020).

Our primary objective is to describe the perioperative anesthetic management of patients with tracheal stenosis undergoing TRR. Secondary objectives are to describe the demography, preoperative condition, and postoperative complications after TRR. Finally, we did an exploratory analysis to identify possible risks factors for postoperative complications after TRR procedures; the analysis was performed between postoperative complications and the following variables: previous balloon dilation, laser resection, the severity of the stenosis, preoperative tracheostomy, duration of surgery, number of rings resected, cervical flexion, airway approach, and anesthetic induction.

For the statistical analysis, categorical variables were presented as percentages and continuous variables as mean and standard deviation. For the post-hoc exploratory analysis described above, we did a bivariate analysis with Student's *t*-test, Chi-Square test, and Fisher's exact test. Statistical significance was set for a p-value less than 0.05.

Two researchers reviewed the preanesthetic assessments records, anesthesia records, and surgical descriptions. Medical, nursing, and respiratory therapy records were also reviewed until hospital discharge and up to one year after surgery.

Exclusion criteria were patients on mechanical ventilation, surgical reintervention, carinal resection, and cases where the anesthesia record in the electronic or physical medical records was not available. This article adheres to the applicable STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) guidelines.

Results

Forty-three patients undergoing TRR were analyzed, evidencing prolonged intubation as the primary cause (72%) for tracheal stenosis, which was found to be of variable degrees of severity. Distribution by sex and age was homogeneous with an average age of 41 years for both genders; their preoperative demographic variables are summarized in Tables 1 and 2. Due to the low number of observations, the statistical tests can be negative secondary to a low power of the study to find difference with a statistical and clinical significance. In every case, the power was below 50%.

Preoperative period

Most frequent symptoms referred before surgery were dyspnea/shortness of breath with exertion (76%), stridor (39%), and dysphonia (13%). Fourteen percent of patients presented with vocal cord paralysis and another 30% had been tracheostomized approximately 36 months (SD ± 34) before TRR. Post-hoc analysis did not find an association of postoperative surgical reintervention for patients who had undergone preoperative tracheostomy ($p = 1.000$).

For preoperative pulmonary function testing, 11% of patients had a normal forced expiratory volume in the first second, with 72% of patients presenting an obstructive ventilatory pattern. Pneumatic balloon dilation (51%) and laser resection (31%) were performed before TRR; 13% and 18% required surgical reintervention, respectively, after TRR. However, in the post-hoc analysis, we did not find an association between previous dilation or laser resection and surgical reintervention ($p = 0.229$ and $p = 0.787$).

Intraoperative period

All patients were monitored in accordance with the American Society of Anesthesiologists (ASA) standards, with 37% requiring additional intra-arterial blood pressure measurement. The induction technique was either intravenous (70%) or inhalational (18%), and 2% of patients required awake intubation; dexamethasone and lidocaine were also

Table 1 Patient characteristics.

Characteristics	Number of patients (n = 43)
Sex	
M (%)	21 (48.8)
F (%)	22 (51.1)
Age (mean in yr, ±SD)	41 (17.4)
BMI (mean in $Kg.m^{-2}$, ±SD)	26.3 (6.7)
ASA	
I (%)	5 (11.6)
II (%)	22 (51.2)
III (%)	14 (32.6)
IV (%)	2 (4.6)
Stridor (%)	17 (39.5)
Dyspnoea on exertion (%)	33 (76.7)
Time of tracheostomy before TRR (mean in months, ±SD)	36 (34)
Comorbidities	
Preoperative tracheostomy (%)	13 (30.2)
Arterial hypertension (%)	14 (32.6)
Coronary heart disease (%)	5 (11.6)
Asthma/COPD (%)	8 (19)
Congestive heart failure (%)	3 (7)
Active smoking (%)	8 (18.6)

BMI, Body Mass Index; ASA, American Society of Anaesthesiologists physical status; TRR, Tracheal Resection and Reconstruction; COPD, Chronic Pulmonary Disease; SD, Standard Deviation.

administered in 88% and 49% of patients, respectively. Endotracheal intubation (either pre-stenosis or trans-stenosis) was performed in 39% of cases, an LMA approach was used in 37% of patients, and stoma site intubation was done in 23% of patients undergoing TRR. In a post-hoc analysis, we did not find an association between airway management and reoperation (p = 0.556). Seventy-six percent of patients received remifentanil and 77% dexmedetomidine during surgery. The intraoperative characteristics are summarized in Table 3.

Table 2 Pre-operative characteristics.

Characteristics	Number of patients (n = 43)
Distance from stenosis to vocal cords (mean in cm, ±SD)	2.99 (1.57)
Stenosis diameter (%)	
0	8 (18.6%)
1—50	5 (11.6%)
51—70	7 (16.3%)
71—99	8 (18.6%)
100	15 (34.9%)
Basal obstructive FEV1 (%)	13 (72.2)
Preoperative pneumatic dilation (%)	22 (51.2)
Preoperative laser resection (%)	17 (39.5)
Etiology of stenosis	
Idiopathic (%)	1 (2.33)
Oncological (%)	11 (25.6)
Previous intubation (%)	31 (72.1)

FEV1, Forced Expiratory Volume in 1 second.

Table 3 Intraoperative characteristics.

Characteristics	Number of patients (n = 43)
Surgical time (mean in minutes, ±SD)	186.5 (63)
Airway	
Laryngeal mask (%)	16 (37.2)
OTI (%)	17 (39.5)
Intubation through tracheostomy (%)	10 (23.3)
Arterial line (%)	16 (37.2)
Rings resected	
2	8 (18.6%)
3	16 (37.2%)
4	12 (27.9%)
5	3 (7%)
6	3 (7%)
10	1 (2.3%)
Maintenance of anaesthesia	
TIVA (%)	11 (26.2)
Balanced (%)	32 (74.4)
Operating room extubation (%)	35 (81.4)
Intraoperative complications	
None (%)	39 (90.7)
Intraoperative cardiac arrest (%)	1 (2.3)
Tracheostomy (%)	2 (4.7)

TIVA, Total Intravenous Anaesthesia; OTI, Orotracheal Intubation.

The surgical technique consisted of resection of the tracheal segments involved with termino-terminal anastomosis, performed in an average of 186 minutes (SD ±63). In all the cases, the distal airway was also intubated on the field to achieve cross-field ventilation and allow tracheal dissection and suturing in a clear field. This was discontinued right after the suture of the posterior wall, and a small size orotracheal tube was advanced into the distal airway to complete the anterior anastomosis.

In 71% of cases, sevoflurane and intravenous infusion of remifentanil were used for maintenance of general anesthesia, titrating FiO_2 to achieve oxygen saturations of about 90% and decrease fire-risk related to oxygen. In this cohort, two patients required preventive tracheostomy at the end of the surgery, one because of previous vocal cord paralysis due to thyroid tumoral infiltration, and the other as a result of an extensive resection (10 rings). One patient had an intraoperative spontaneous tension pneumothorax, requiring cardiopulmonary resuscitation and tracheostomy at the end of the surgery.

Postoperative period

In the Intensive Care Unit (ICU), 49% of patients received an infusion of dexmedetomidine for sedation and analgesia, without reports of respiratory depression. Food and fluids were withheld for an average of 2.5 days. Average length of

Table 4 Postoperative characteristics.

Characteristics	Number of patients (n = 43)
Dexmedetomidine (%)	21 (48.8)
Head flexion (%)	30 (69.8)
Head flexion (mean in days, ±SD)	5 (2)
Fasting (mean in days, ±SD)	2.5 (2)
ICU (mean in days, ±SD)	6.9 (12.52)
Length of hospital stay (mean in days, ±SD)	12.1 (15.2)
Postoperative complications	
Ventilatory support (%)	9 (20.9)
Vocal cord paralysis (%)	11 (25.6)
Suture dehiscence (%)	3 (7)
Surgical site infection (%)	5 (11.6)
Postoperative tracheostomy (%)	6 (14)
Mortality in 30 days (%)	1 (2.3)

ICU, Intensive Care Unit.

Figure 1 Cervical flexion with chin-sternum suture and cervical stability, HUSI technique. Soucer: Authors.

ICU stay and following inpatient care were 6.9 and 12.1 days, respectively.

Major postoperative complications were vocal cord paralysis (25.6%), postoperative ventilatory support (20.9%), and need for surgical reintervention (20.9%). One patient died in the postoperative period due to massive hemoptysis and neck hematoma Table 4. depicts the postoperative characteristics of patients undergoing TRR.

Among those patients, 53.48% had Myer-Cotton grade III and IV tracheal stenosis,[13] 17.39% of them required reoperation; however, we did not find a statistical association between severity of the stenosis and reintervention (p = 0.478). Reoperation occurred among 8.3% of patients with resection of fewer than four rings and 36.8% of patients with more than four rings resected. However, no association was found between the number of rings resected and reintervention (p = 0.163). In 69.77% of cases, cervical flexion with the head in a neutral position was required (Fig. 1), but no association was found between flexion and surgical reintervention (p = 0.820). Finally, patients who did not require surgical reintervention had shorter surgical time than the patients who required surgical reintervention (95% CI -108, -18.9; p = 0.006).

Discussion

Preoperative assessment

Our principal cause of TRR was previous intubation, which is consistent with what has been described in previous literature.[2,3] Demographic findings (age, sex, and BMI) support the observations of the previous cohort reported by Wright et al., where men are equally affected compared to women and age distribution is mainly in middle-aged adults.[2]

Interestingly, a significant majority of our patients had none or optimally controlled comorbidities (ASA I and II), while other authors report the presence of chronic diseases but fail to specify their ASA physical status.[2-4,9,14] Diabetes mellitus is a well-documented risk factor for postoperative complications (OR = 3.32)[2] due to the microvascular injuries and decreases in perfusion to the tracheal anastomoses; however, we could not report associations because none of our patients had this diagnosis.

In this cohort, patients with a history of prolonged ICU length of stay had a previous tracheostomy to secure the airway and then were referred to our institution for TRR. Nonetheless, previous tracheostomy was not associated with postoperative reintervention in contrast to Wright's larger cohort in which preoperative tracheostomy was indeed linked to anastomotic complications (OR = 1.79).[2]

It is unclear if TRR was an urgent procedure in previous cohorts reported.[2-4,9,14] All our TRR were elective surgeries, whereas urgent preoperative interventions were tracheostomy, balloon dilation, or laser resection. These interventions permit maintaining a patent airway and may allow a period for medical optimization before TRR.[12]

Surgical planning in our hospital includes preoperative flexible bronchoscopy to evaluate vocal cord dysfunction, establish the distance from the vocal cords to the stenosis, and its severity. Interestingly, our patients' stenosis diameters were not associated with the need for reintervention, but more extensive studies are needed to evaluate this association and if it has a clinical significance.

Even though we performed preoperative balloon dilation and laser resection with a flexible bronchoscope through a LMA, other authors report these procedures with the use of a rigid bronchoscope.[15] This analysis did not find an association between previous dilation or laser resection with surgical reintervention; those results are following Hentze et al., who found that preoperative intervention is not a risk factor for postoperative complications.[14]

Intraoperative management

There are different anesthesia induction techniques described in the literature for severe stenosis.[12,16] Our intraoperative complications were not linked to anesthetic induction, which supports the observation of the previous cohort reported by Krecmerova et al.[9] Although our principal anesthetic induction was intravenous (79.07%) with no adverse events reported, it is unclear which technique is best suited for severe stenosis. Another study performed spirometry before and after anesthetic induction in patients undergoing TRR for laryngotracheal stenosis and found that intravenous induction with neuromuscular relaxation, LMA, and positive pressure volume ventilation have better air flows through severe extra thoracic stenosis compared to the spontaneous breathing efforts of the awake patient.[17] Therefore, we consider that further studies are necessary to evaluate if anesthetic induction has a clinical significance or if it is associated with intra- or postoperative complications.

In our study, different types of airway approaches were performed, and no relationship was found with postoperative reintervention. However, in recent years we have favored the use of LMAs, especially for subglottic stenosis where intubation may be difficult, without adverse events, which is consistent with Krecmerova's cohort. The authors suggest that LMA can be an option for airway management because it allows a patent airway and a fiberoptic view through the device, without an increased risk of serious complications (i.e., pulmonary aspiration, early postoperative bleeding, or suture dehiscence).[9] The potential advantages of using LMAs are that tracheal intubation is not required,[18] there may be better exposure and visualization of the surgical field, decrease in the operating time,[19] and LMA can be used with high-frequency jet ventilation.[6] Besides, possible risks associated with tracheal intubation in tracheal stenosis are avoided: hypoperfusion of the mucosa at the site of the cuff, and injury by ischemia and reperfusion.[20]

We do not have experience with other anesthetic approaches previously reported such as: regional anesthesia (cervical epidural, nerve blocks like bilateral superficial cervical plexus, thoracic paravertebral, vagal nerve, or phrenic nerve block), sedation with spontaneous ventilation, or extracorporeal support, that have an overall failure rate of 1.8% as reported in the literature.[7,11] There might be some advantages like feasible and faster anastomosis and high level of patient satisfaction with no difference in postoperative complications; however, the benefits of non-intubated airway surgery over intubated surgery remain unclear.[19,21,22]

All our patients had cross-field ventilation, which is consistent with what has been previously described in 93.2% of cases.[11] Cuff rupture is a possible complication of this ventilation that can be present in up to 20% of cases;[11] however, we did not find any complications related to it.

Despite the existing controversy about the use of steroids and the potential risk of suture dehiscence,[23] 88% of our patients received dexamethasone intraoperatively (4–8 mg) for prevention of postoperative nausea and vomiting and post-extubation laryngeal edema.[23,24] Among the three cases who had suture dehiscence, only one patient received steroids. This supports the observations of the previous cohort reported by Wright et al where the use of steroids was not a risk factor for anastomotic complications.[2]

The average time of surgery was 186 minutes; we found no difference in duration over the years. There was a statically significant difference in the time of surgery among those patients who required reintervention and those who did not; moreover, in thoracic surgery, prolonged operative time ($\geq$ 240 min) is associated with an increased risk of complications (OR = 2.51).[25] In our cohort, the patients who required prolonged surgeries had an average of more than four tracheal rings resected. However, although we did not find an association between the number of rings resected and postoperative surgical reintervention, resections $\geq$ 4 cm have been described as a risk factor of postoperative complications (OR = 2.01).[2]

Postoperative outcomes

In this cohort, dexmedetomidine was our first line of treatment in the ICU for analgesia and conscious sedation without having any respiratory depression events. These findings follow the observation described by Fiorelli et al., where dexmedetomidine provided safe and effective sedation after TRR. It is paramount to bear in mind that dexmedetomidine significantly decreases mean arterial pressure and heart rate.[26] However, further studies are needed to compare the best treatment strategy for analgesia and sedation in the postoperative care of these patients.

Most patients had cervical flexion with chin to chest sutures to decrease mobility (neck extension) and secondary tension in the tracheal anastomosis.[27] A posterior splint for maintaining the neutral position was described by Mueller DK et al. as an alternative method to decrease movement of the cervicothoracic area while reducing lateral movement. They use the splint for an average of one week, similar to the flexion times used in our patients.[28] In our case, in addition to fixation sutures, pneumatic bags are used to prevent lateral movement (Fig. 1).

Interestingly, many of our patients were extubated in the operating room as other authors reported without presenting immediate adverse events.[9,14] These findings contrast with other authors' cohorts, where an uncuffed nasal endotracheal tube is left in place during the first postoperative day and then removed after bronchoscopic review of the anastomosis.[26] Early extubation avoids positive pressure or endotracheal tube cuff trauma to the new anastomosis, factors that may contribute to anastomotic complications. If extubation cannot be performed, keeping spontaneous ventilation with a small-caliber tube without insufflating the cuff is recommended, with another extubation attempt 24 hours later, under direct supervision. If this attempt fails, it is suggested to perform a tracheostomy 2-cm distal from the anastomosis.[12] However, it remains unclear whether early extubation has, in fact, any benefits over late extubation.

TRR has a success rate greater than 95% and a mortality of 1–2%, similar to what was found in our study.[2-4,9,29] The patient who died in our institution had an anastomotic complication. Despite a low mortality rate, this surgery has a high frequency of complications (15–39%), which could possibly be related to anastomotic-related issues.[2,29,30] Non-anastomotic complications are infection, bleeding, vocal cord dysfunction, edema, pneumonia, arrhythmias, myocardial infarction, and pulmonary embolism. Anastomotic complications are dehiscence, granulomas, and restenosis, with an incidence of 9% and a mortality of 7.4%.[2] However, we did not find an association between our anesthetic management and postoperative complications. Therefore, there is uncertainty about the impact of anesthetic interventions on anastomotic or non-anastomotic complications.

Our study has several limitations. First, although we describe our ten years of experience, a small sample size could reflect a lower experience of our service in this type of surgery than a more specialized center. Second, it is a retrospective analysis and might have an underlying reporting bias. Finally, perioperative anesthetic management has changed over the years, reflecting heterogeneity in patient management; thus, it may explain why we did not find the associations in the analysis described above.

In conclusion, perioperative management of TRR at our hospital has a low mortality and high morbidity rate. We did not find an association between perioperative anesthetic interventions and postoperative complications. Moreover, to reflect possible evidence gaps, this article highlights several differences in contemporary practice. Therefore, we acknowledge that additional studies are needed to evaluate if anesthetic interventions (airway management, anesthetic induction, early extubation, or postoperative sedoanalgesia) may be associated with better outcomes.

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Conflicts of interest

The authors declare no conflicts of interest.

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