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COVID-19-Related Post-Intubation Tracheal Stenosis. Prospective Study of its Surgical Treatment

Estenosis traqueal posintubación asociada a COVID-19. Estudio prospectivo sobre su tratamiento quirúrgico

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ABSTRACT

Introduction: The disease caused by SARS-CoV-2 has become a significant public health issue. 5 % of the patients required endotracheal intubation due to acute hypoxemic respiratory failure, leading to an increased number of consultations for tracheal stenosis. This work was done with the aim of presenting the results of tracheal resection in patients with post-COVID-19 stenosis.

Material and methods: Analytical, prospective, observational study. 11 patients were included. The preoperative and postoperative evaluation was the same for all patients. Post-surgical ventilation and phonation were assessed up to 30 days. The Clavien and Dindo classification was used to grade post-surgical complications, with follow-up extended up to 60 post-surgical days. Statistical analysis: the Wilcoxon test was used to compare the results.

Results: 27.2 % of the patients had postoperative complications. The comparison of pre- and postoperative ventilation ($p < 0.05$) was statistically significant, with improvement in the postoperative period. When comparing pre- and postoperative fiberoptic bronchoscopy (tracheal lumen diameter), the result was also statistically significant ($p < 0.05$).

Conclusion: The results obtained are similar to those expressed in the literature. Tracheal resection is a safe and effective procedure and should be considered as first-line treatment for tracheal stenosis.

Key words: Coronavirus; Tracheal stenosis; Intubation, Intratracheal; Thoracic surgery

RESUMEN

Introducción: La enfermedad por SARS-CoV-2 se convirtió en un importante problema de salud pública. El 5 % de los pacientes requirió intubación endotraqueal por insuficiencia respiratoria aguda hipoxémica, y se generó un aumento de consulta por estenosis traqueal. Se realizó el trabajo con el objetivo de expresar los resultados de la cirugía de resección traqueal en pacientes con estenosis post COVID 19.

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Material y métodos: Estudio prospectivo, observacional, analítico. Se incluyeron 11 pacientes. La evaluación prequirúrgica y postquirúrgica fue la misma en todos los pacientes. Se valoró en el postquirúrgico la ventilación y la fonación hasta los 30 días. Se utilizó la clasificación de Clavien y Dindo para calificar a las complicaciones postquirúrgicas, con seguimiento hasta los 60 días postquirúrgicos. Análisis estadístico: se aplicó prueba de Wilcoxon para comparar los resultados.
Resultados: El 27.2 % de los pacientes tuvieron complicaciones postquirúrgicas. Fue estadísticamente significativa la comparación de la ventilación entre el prequirúrgico y el postquirúrgico (p<0.05) con mejoría en el postquirúrgico. Al comparar la fibrobroncoscopía prequirúrgica con la postquirúrgica (diámetro de la luz traqueal) también el resultado fue estadísticamente significativo (p <0.05).
Conclusión: Los resultados obtenidos son similares a los expresados en la literatura. La cirugía de resección traqueal es un procedimiento seguro y efectivo y debe ser considerada como tratamiento de primera línea para la estenosis traqueal.

Palabras claves: Coronavirus; Estenosis Traqueal; Intubación, Intratraqueal; Cirugía Torácica

INTRODUCTION

The disease caused by SARS-CoV-2 (COVID-19) spread rapidly worldwide and has become a significant public health issue. The first case was reported in 2019. This led to an unprecedented increase in the number of patients requiring prolonged stays in the Intensive Care Unit (ICU) due to respiratory complications caused by COVID-19. 5 % of these patients required endotracheal intubation and mechanical ventilation for acute hypoxemic respiratory failure.[1, 2]

While orotracheal intubation (OTI) is an essential tool for the management of patients in the intensive care unit, one of the complications it can generate is tracheal stenosis. Although the incidence is low at present, thanks to applied new technologies, it still exists. These advances began to be used after research conducted by Grillo and Cooper in 1966,[3] where they determined the physiopathology of tracheal stenosis. The rate of laryngotracheal stenosis postintubation (LSPI) in non-COVID-19 patients is between 10 and 22 %.[4, 5] Although the rate of LSPI related to COVID-19 is still unknown, it is believed that this complication is even more common.[6] This could possibly be due to the debate regarding the timing of the tracheostomy that took place at the beginning of the pandemic (due to the risk of virus aerosolization), leading to many cases being performed late.[7]

We present the experience in managing a series of consecutive patients who underwent surgical treatment.

OBJECTIVES

Primary

To assess the results of the surgery in relation to ventilation and phonation.

Secondary

1. To determine surgery-related morbidity and mortality according to the Clavien Dindo scale.
2. To compare our results with those of the series of patients (with and without COVID-19) mentioned in the literature.

MATERIALS AND METHODS

An analytical, prospective, observational study was conducted. A database was created, including the patients who underwent tracheal resection with primary anastomosis at the Sanatorio Allende, New Córdoba and Cerro branches (Córdoba city, capital of the Province of Córdoba, Argentina) between August 2021 and September 2022.

All patients signed an informed consent prior to surgery.

The study was reviewed and approved by the Ethics Committee of the Sanatorio Allende.

Inclusion criteria

- Patients of both sexes, aged 16 and older, diagnosed with complex central airway stenosis following prolonged intubation with mechanical respiratory support as a treatment for COVID-19.

Exclusion criteria

- Patients with tracheal stenosis greater than 5 centimeters and/or with general contraindications for surgical treatment.

All the patients had a standard evaluation. They underwent axial, coronal and sagittal computed tomography scans (CT) and flexible fiberoptic bronchoscopy (FFB). With the CT and FFB results, both the length and location of the stenosis were determined.

A complex tracheal stenosis is considered to be one exceeding 1 cm in length and with involvement of the tracheal wall. Cases were classified according to the Myer-Cotton classification.[8]

In patients where the stenosis affected the cricoid cartilage, laryngotracheal resection was considered.

The surgical technique is similar to that described by Mathisen[9] with a few modifications.

To the patient with tracheoesophageal fistula, closure of the opening on the anterior face of the esophagus was performed using 3.0 silk sutures on the mucosa and muscular layers separately. Regarding anesthesia, all patients received either inhalation gas or total intravenous anesthesia. In patients with severe tracheal stenosis, tracheal dilation was performed prior to the placement of the orotracheal tube. At the end of the surgery, the patients were extubated.

To assess ventilation and phonation, patients were evaluated at 7 days, 15 days, and 30 days post-surgery.

Ventilation was assessed basing on the presence or absence of stridor in the postoperative period.

Phonation was assessed basing on the presence or absence of dysphonia in the postoperative period.

The Clavien and Dindo classification was used to grade postoperative complications, with follow-up extended up to 60 days.

A new FFB was conducted on all patients after 30 days to evaluate the status of the anastomosis.

Statistical analysis

All the variables in research were expressed in percentages, maximum, minimum, and median.

The Wilcoxon test was used to compare the presence or absence of stridor on days 7, 14, and 30 after surgery in patients who presented stridor as initial symptom, considering a p-value < 0.05 as statistically significant.

The Wilcoxon test was also applied to compare preoperative and postoperative fiberoptic bronchoscopy, taking into account whether the postoperative fiberoptic bronchoscopy showed a preserved tracheal lumen diameter or not; the statistically significant value was $p < 0.05$.

RESULTS

Out of the 19 initially evaluated patients, 8 were excluded, resulting in a final sample size of 11 participants. (Figure 1)

Of the included patients, 9 (81.8 %) were male, with a mean age of 52 years (MAX: 72 MIN: 32 MEDIAN: 47). Table 2 shows the medical record, surgical risk (ASA score), pre-surgery treatment, history of corticosteroid use, and postoperative complications (Clavien Dindo classification). 27.2 % of the patients had postoperative complications.

References: Sx: surgery/ COPD: chronic obstructive pulmonary disease/AHT: arterial hypertension/

TABLE 1. Shows which variables were researched

Variables of research
Demographic variables
Sex
Age
Variables related to the patient
Medical history
Previous use of corticosteroids
Preoperative risk ASA score (American Society of Anesthesiologists)
Variables related to tracheal stenosis
Number of days of OTI
Tracheostomy
Presenting symptom
Characteristics of preoperative CT and FFB
Variables related to surgery
Type of resection
Length of laryngotracheal resection
Postoperative complications (Clavien and Dindo classification)
Variables related to results
Clinical assessment
Postoperative FFB

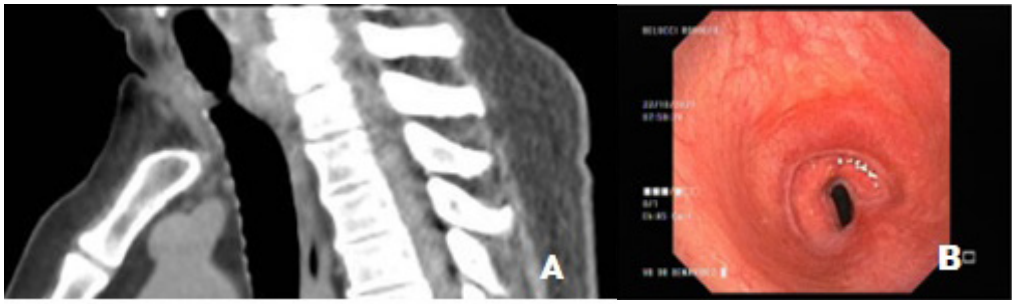

Figure 1. Assessment of tracheal stenosis with CT and FFB).
A: Neck CT scan (sagittal cut) showing tracheal stenosis at the cervical level
B: FFB revealing reduced tracheal diameter, with involvement of the tracheal wall)

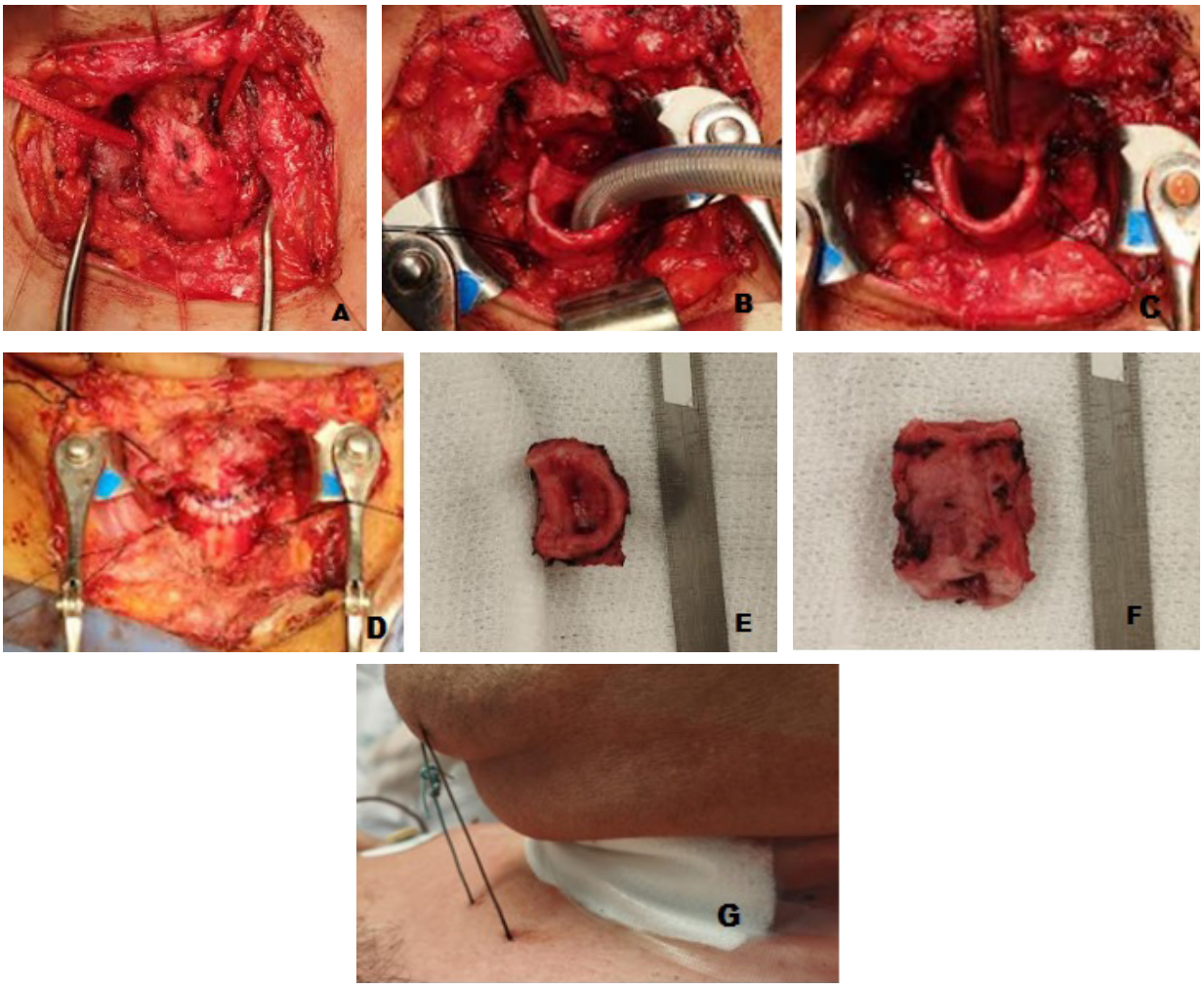

Figure 2. Surgery explained step-by-step)
A: Tracheal dissection
B: Sectioned trachea and direct tracheal intubation
C: Posterior face anastomosis with continuous sutures with polyglactin 3.0
D: Anterior face anastomosis with separate sutures with polyglactin 3.0
E: Coronal view of resected tracheal segment. Severe stenosis is observed.
F: Longitudinal view of resected tracheal segment.
G: Mento-sternal safety point).

DBT: diabetes/ DVT: deep venous thrombosis/ HAP: hospital-acquired pneumonia

Only one patient was diagnosed with COVID-19 in the year 2020; the rest were diagnosed in 2021.

All the patients had OTI, with an average of 13 days (MAX: 21 MIN: 8 MEDIAN: 12). 5 patients (45.4 %) underwent a tracheostomy. The average of days between the OTI and the tracheostomy was 13 (MAX: 20 MIN: 9); and 3 patients (27.2 %) remained with the tracheostomy until surgery; 2 of them due to total laryngotracheal occlusion and the rest due to tracheoesophageal fistula.

The presenting symptoms and reasons for consultation were as follows: stridor and dyspnea (36.3 %), stridor only (27.2 %), aphasia (18.1 %), stridor, dyspnea, and dysphonia (9 %), and bronchoaspiration (9 %). The results observed in the neck CT and FFB are detailed in Table 3.

References: n/s: not specified

According to the Myer-Cotton classification, 8 patients were grade 2; 2 patients were grade 4, and 1 patient was grade 3.

The average number of months between the diagnosis of COVID-19 and tracheal resection surgery was 7 (MAX: 25 MIN: 2).

54.4 % of the patients required at least one tracheal dilation prior to surgery. One of the patients underwent endoscopic treatment using argon plasma without the expected results before surgery.

Laryngotracheal resection was performed on 36.3 % of the patients, and tracheal resection on 63.6 %.

The average duration of surgery, measured in minutes, was 191 (MAX: 240 MIN: 120). The average hospital stay was 6 days (MAX: 7 MIN: 5). Only

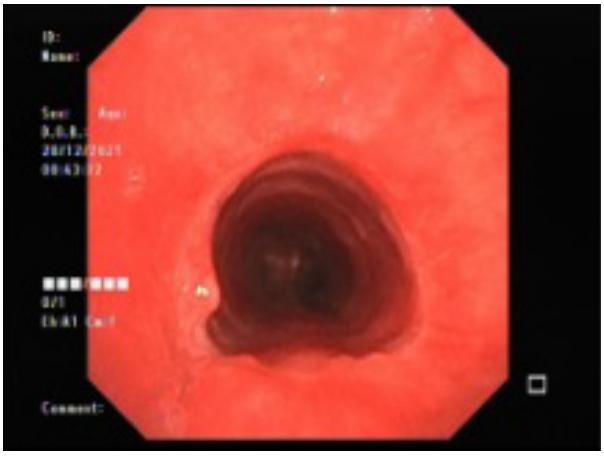

Figure 3. FFB 30 days after surgery. Description: The diameter of the tracheal lumen is observed to be preserved

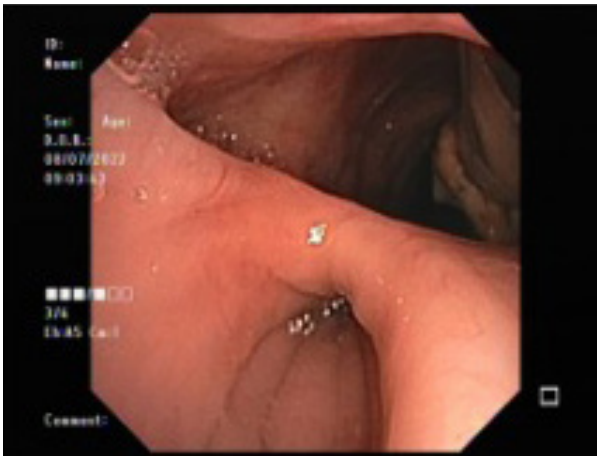

Figure 4. FFB of tracheoesophageal fistula. Description: Communication between the airway (above) and the esophagus (below) is observed

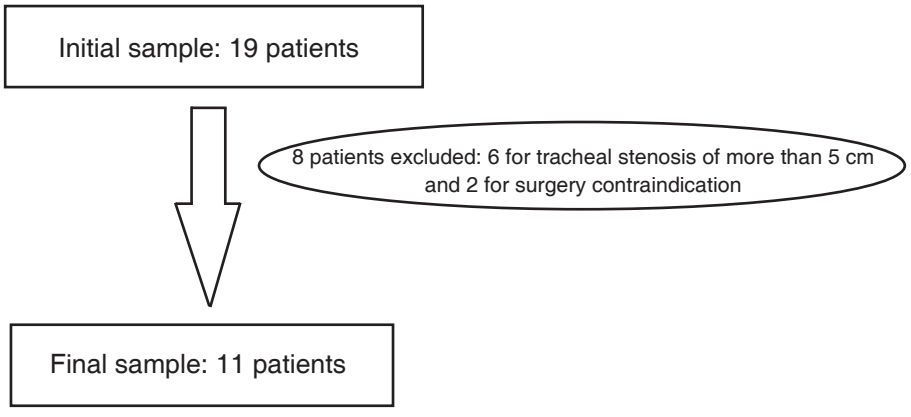

Figure 5. Sample composition

one patient required surgical reintervention due to dehiscence of the anastomotic suture 47 days after surgery.

The average resection length (measured in cm) was 2.9 (MIN: 1.5 MAX: 5).

There was no mortality at 60 days.

In the assessments at 7 and 14 days post-surgery, 5 patients showed dysphonia.

At the 30-day assessment, 4 patients experienced dysphonia.

In the postoperative period, endoscopic treatment with argon plasma was performed in only 1 patient for granulomas at the anastomotic level.

Statistical analysis

Regarding the assessment of preoperative stridor compared to the control at 7 days, no patients showed stridor; and the same was observed at 14 days. Only one patient exhibited stridor at 30 days. In this comparison, 8 patients were included, as 3 patients maintained the tracheostomy until surgery, making the symptom unassessable.

The result of the comparison between preoperative stridor and the assessment of the presence of this symptom at 7, 14, and 30 days was statistically significant in all cases ($p < 0.05$) (Table 4).

In the comparison between the initial FFB and that of 30 days post-surgery, only one patient exhibited a decrease in the diameter of the tracheal lumen. The result was statistically significant ($p > 0.05$) (Table 5).

DISCUSSION

The approach to treat benign tracheal stenosis is very complex, so it should be carried out in highly experienced centers. It requires a trained team to do a proper evaluation and determine the best treatment option, with tracheal resection and primary anastomosis being one of the choices.

There are very few studies in the literature that show the results of tracheal surgery for benign stenosis, and if we specifically focus on tracheal or laryngotracheal resection for stenosis secondary to intubation from COVID-19, we find only two studies, with the rest being case reports.

Regarding our results, the most prevalent symptom in the postoperative period was dysphonia, but it was mild in all the cases, and it didn't prevent the patients from carrying out their daily activities normally. Only one patient required endoscopic treatment related to dysphonia, specifically due to granulomas on the vocal cords.

TABLE 2. Data related to the patient and postoperative complications

Patient	Medical record	ASA	Pre-surgery treatment (No. of dilations)	Corticosteroids used until Sx	Postoperative complications	Clavien and Dindo classification
1	No	3	Dilation (1)	NO	NO	
2	COPD/STROKE	2	No	NO	HAP	II
3	AHT/Obesity	2	Dilation (1)	YES	NO	
4	AHT	3	Dilation (1)	NO	NO	
5	AHT/DBT/Obesity/ COPD	2	Dilation (2)	NO	Cellulitis	II
6	DBT	3	Endoscopic treatment with argon plasma	NO	NO	
7	DBT- Obesity	2	Dilation (5)	YES	Dehiscence of anastomosis	IV
8	NO	2	Tracheostomy until surgery	NO	NO	
9	NO	2	Dilation (2)	NO	NO	
10	Obesity	2	Tracheostomy until surgery	NO	NO	
11	DVT		Tracheostomy until surgery	NO	NO	

References: Sx: surgery/ COPD: chronic obstructive pulmonary disease/AHT: arterial hypertension/ DBT: diabetes/ DVT: deep venous thrombosis/ HAP: hospital-acquired pneumonia

TABLE 3. Data obtained from the CT and FFB

Patient	CT	FFB
1	Location: cervical trachea Length: 15 mm Lumen reduction: yes	Location: cervical trachea Length: 3 cm Lumen reduction: 60 %
2	Location: cervical trachea Length: 7 mm Tracheal lumen: 5 mm	Location: laryngotracheal Length: 3 cm Lumen reduction: 70 %
3	Location: cervical trachea Length: 7 mm Lumen reduction: n/s	Location: cervical trachea Length: 2 cm Lumen reduction: 70 %
4	Location: cervical trachea Length: 10 mm Tracheal lumen 10 mm	Location: cervical trachea Length: 3 cm Lumen reduction: 70 %
5	Location: n/s Length: n/s Lumen reduction: n/s	Location: cervical trachea Length: 2.5 cm Lumen reduction: 60 %
6	Location: cervical trachea Length: 10 mm Lumen reduction: n/s	Location: cervical trachea Length: 4 cm Lumen reduction: 50 %
7	Location: laryngotracheal Length: 15 mm Lumen reduction: 60 %	Location: laryngotracheal Length: 3 cm Lumen reduction: 60 %
8	Location: tracheal Length: n/s Lumen reduction: 100 %	Location: tracheal Length: n/s Lumen reduction: 100 %
9	Location: laryngotracheal Length: n/s Lumen reduction: n/s	Location: laryngotracheal Length: 2 cm Lumen reduction: 90 %
10	Location: tracheal Length: n/s Lumen reduction: 100 %	Location: tracheal Length: n/s Lumen reduction: 100 %
11	Tracheoesophageal fistula at the cervical trachea level	Location: tracheal Length: 2 cm Lumen reduction: 60 %

References: n/s: not specified

27.7 % of the patients showed postoperative complications, with two being classified as mild (Clavien Dindo II) and one more severe: dehiscence of the anastomotic suture (Clavien Dindo IV), which required emergency tracheostomy and was a late complication, occurring 47 days post-surgery. This case was the patient whose FFB showed a decrease in the tracheal lumen 30 days post-surgery. Upon analyzing the complications, it is observed that all three patients were classified as ASA 3, and the patient with the most severe complication continued using corticosteroids until the surgery and had undergone 5 previous dilations. These are known risk factors for tracheal resection surgery.[10]

The most common presenting symptom was stridor, which was taken into account when assessing ventilation in the postoperative period. When comparing the preoperative period with control at days 7, 14, and 30 after surgery, the difference in the absence of stridor was always statistically significant ($p < 0.05$), indicating the positive outcomes of the surgery. The same trend was observed when comparing the preoperative FFB with the one performed 30 days after surgery. The result was also statistically significant ($p < 0.05$) for the preserved tracheal lumen diameter in the postoperative period, which correlates with the absence of stridor and underscores the success of the surgical treatment.

Piazza's work[11] is the only one in the literature showing the results of a case series involving tracheal or laryngotracheal resection secondary to tracheal stenosis caused by COVID-19. The number of patients treated in that study is 14,

TABLE 4
Comparison between preoperative stridor and stridor 7 days post-surgery
Wilcoxon Test (paired samples)
P-value estimated by sampling of all possible permutations (n = 5000)

Obs (1)	Obs (2)	N	Sum (R+)	E (R+)	Var (R+)	Z	P (2 tails)
Initial symptom	7 days pos-Sx	8	36.00	18.00	40.50	2.83	<0.0001

Comparison between preoperative stridor and stridor 14 days post-surgery
Wilcoxon Test (paired samples)
P-value estimated by sampling of all possible permutations (n = 5000)

Obs (1)	Obs (2)	N	Sum (R+)	E (R+)	Var (R+)	Z	P (2 tails)
Initial symptom	14 days pos-Sx	8	36.00	18.00	40.50	2.83	<0.0001

Comparison between preoperative stridor and stridor 30 days post-surgery.
Wilcoxon Test (paired samples)
P-value estimated by sampling of all possible permutations (n = 5000)

Obs (1)	Obs (2)	N	Sum (R+)	E (R+)	Var (R+)	Z	P (2 tails)
Initial symptom	30 days pos-Sx	8	36.00	18.00	40.50	2.83	<0.0001

TABLE 5
Comparison between preoperative and postoperative tracheal lumen
Wilcoxon Test (paired samples)
P-value estimated by sampling of all possible permutations (n = 5000)

Obs (1)	Obs (2)	N	Sum (R+)	E (R+)	Var (R+)	Z	P (2 tails)
Pre-Sx tracheal lumen diameter	Post-Sx tracheal lumen diameter	11	65.00	33.00	105.88	3.11	<0.0001

very similar to our experience. The mean age of the patients and the male-to-female ratio are also similar. In their study, the mean duration of the OTI was 15.2 days, and a tracheostomy was performed on 10 patients. In our work, the mean duration of the OTI was 13 days, and a tracheostomy was performed on 5 patients. Just like in our work, 3 patients arrived to the surgery with a tracheostomy.

With regard to the location, in both studies, the most frequent location was the cervical trachea. The most commonly performed procedure on patients before surgery was tracheal dilation. In Piazza's work,[11] the mean time of hospitalization was 12.1 days, compared to 6 days in our study. They documented a case of restenosis, whereas we had none in our study.

Another study that shows results of tracheal surgery in patients with stenosis secondary to prolonged intubation is the one from Palacios[12]. However, it includes various tracheal procedures (tracheal resection, Montgomery T-tube placement, endoscopic treatment), and in the description of the results, it does not specify the technique that was used. The most frequently affected site was the cervical trachea. According to the Myer-Cotton grading system, the majority of the cases were grade III; in our work, the majority were grade II.

The remaining articles are related to tracheal surgery for tracheal stenosis but not specifically associated with COVID-19.

Wright's work,[10] evaluates the results of 392 patients operated on at the Massachusetts General Hospital from 1993 to 2017. The mean number of tracheal resections performed per year is 16.3; this figure aligns with the significant number of patients included in our study. The study states

that the most common presenting symptoms are stridor, dyspnea, cough, and dysphonia, very similar to those observed in our patients. In Wright's study, 92 % of patients received some form of treatment before surgery, compared to 63.6 % in our patient series. The mean length of tracheal resection was very similar, with 3 cm in Wright's work and 2.9 cm in ours. The best outcomes were obtained in patients without prior treatment for tracheal stenosis and without prior use of corticosteroids. That is why it is very important not to delay the diagnosis.[13]

The overall morbidity rate was 33 % in Wright's study versus 27.7 % in our work. There was dehiscence of anastomosis in 4 % of Wright's patients compared to 9 % (1 patient) in our series. Similar to our findings, in Wright's study there were no significant differences between pure tracheal resection and laryngotracheal resection.

The study by Natuta[14] reveals the results of 43 patients who underwent tracheal resection between 2007 and 2018, with a mean follow-up of 58 months. Similar to our findings, the study did not report any deaths within the first 30 days. Dyspnea was measured using the visual analogue scale for dyspnea, showing a noticeable improvement in the postoperative period with statistically significant results. Regarding voice assessment, it was determined that 30 patients experienced mild deterioration.

The results presented in the series of patients who underwent tracheal or laryngotracheal resection for benign stenosis unrelated to COVID are similar to those obtained in our study. This suggests that this condition should not significantly alter the treatment approach.

As for the limitations of the study, it should be noted that the number of cases does not allow for statistical analysis to relate variables studied in our work and compare them with the results of non-COVID-19 patients.

CONCLUSION

The COVID-19 pandemic posed a significant challenge for healthcare professionals worldwide. There was a substantial increase in patient admissions to critical care units with the need for OTI. Initially, due to concerns about virus aerosolization, changes in guidelines were implemented, leading to delays in performing tracheostomies. These factors contributed to an increased rate of tracheal stenosis.

For complex tracheal stenosis, it is crucial to have a team with experience in tracheal surgery. With appropriate indications, tracheal resection with primary anastomosis should be considered the first option. In the hands of experienced surgeons, it is a safe and effective procedure.

The postoperative results in this series of patients are similar to those with benign tracheal stenosis unrelated to COVID-19.

A multicenter study should be conducted to increase the number of cases and obtain more significant results.

Conflict of interest

The authors declared no conflict of interest

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