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ORIGINAL ARTICLE

Complex Post-intubation Tracheal Stenosis in Covid-19 Patients

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Abstract

Management of tracheal complications due to endotracheal intubation in patients with coronavirus disease-2019 (COVID-19) is an important concern. This study aimed to present the results of patients who had undergone tracheal resection and reconstruction due to COVID-19-related complex post-intubation tracheal stenosis (PITS). We evaluated 15 patients who underwent tracheal resection and reconstruction due to complex PITS between March 2020 and April 2021 in a single center. Seven patients (46.6%) who underwent endotracheal intubation due to the COVID-19 constituted the COVID-19 group, and the remaining 8 patients (53.4%) constituted the non-COVID-19 group. We analyzed the patients' presenting symptoms, time to onset of symptoms, radiological and bronchoscopic features of stenosis, bronchoscopic intervention history, length of the resected tracheal segment, postoperative complications, length of hospital stay, and duration of follow-up. Six of the patients (40%) were female, and 9 (60%) were male. Mean age was 43.3 ± 20.5. We found no statistically significant difference between the COVID-19 and non-COVID-19 PITS groups in terms of presenting symptoms, time to onset of symptoms, stenosis location, stenosis severity, length of the stenotic segment, number of bronchoscopic dilatation sessions, dilatation time intervals, length of the resected tracheal segment, postoperative complications, and length of postoperative hospital stay. Endotracheal intubation duration was longer in the COVID-19 group than non-COVID-19 group (mean ± SD: 21.0 ± 4.04, 12.0 ± 1.15 days, respectively). Tracheal resection and reconstruction can be performed safely and successfully in COVID-19 patients with complex PITS. Comprehensive preoperative examination, appropriate selection of surgery technique, and close postoperative follow-up have favorable results.

Keywords COVID-19 · SARS-CoV-2 · Novel coronavirus · Post-intubation · Tracheal stenosis · Tracheal resection

Introduction

The coronavirus disease-2019 (COVID-19) pandemic caused by severe acute respiratory syndrome coronavirus type 2 (SARS-CoV-2) has caused a global health crisis. Despite its asymptomatic or mildly symptomatic clinical course in most infected individuals, the disease has been reported to cause acute hypoxemic respiratory failure resulting in mortality at a rate of 2% [1]. To reduce aerosol formation in patients with acute respiratory failure, investigators have recommended using invasive mechanical ventilation (IMV) instead of a high-flow nasal cannula or non-invasive ventilation [2]. Prolonged endotracheal intubation (EI) is frequent in COVID-19 patients who require IMV [3].

Post-intubation tracheal stenosis (PITS) is the most common complication of prolonged endotracheal intubation. The capillary perfusion pressure of the tracheal mucosa varies between 20 and 30 mmHg. Endotracheal tube's (ETT) cuff pressure above 30 mmHg causes mucosal ischemia [4, 5]. Tracheal epithelium damage in short-term ischemia heals with epithelial regeneration. Prolonged ischemia entails damage in the submucosa and the epithelium's full thickness. In this case, mucosal regeneration is insufficient, and healing requires scar formation by collagen deposition [6]. That type of healing manifests with varying degrees of

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circumferential scarring. A longer duration of cuff compression also leads to ischemic injury to the tracheal rings fed by diffusion from the mucosa. Inflammation of the cartilage due to an ischemic injury can be partial or full thickness. Depending on the degree of inflammation, malacia, stenosis, and even perforation (fistula) may develop in the affected tracheal segments [4, 5].

PITS is clinically divided into simple and complex types [7]. Simple PITS are ring-shaped circumferential stenosis less than 1 cm in length without the involvement of the cartilage. Complex PITS are stenosis more than 1 cm in length, accompanied by cartilage involvement in the form of fibrosis or malacia. COVID-19 patients are thought to be more prone to tracheal injuries. Several mechanisms related to COVID-19 management that increase the susceptibility of the trachea to intubation complications are prolonged intubation, prone positioning, impaired laryngotracheal and esophageal microcirculation due to prothrombotic and antifibrinolytic state of the patients, high viral replication in the tracheal epithelium could weaken the mucosa, attenuated tracheal mucosa due to high-dose corticosteroid usage, increased hypoxia of the tracheal mucosa, existing comorbidities, and impaired nursing service due to workload of pandemic [8]. The frequency and management of tracheal complications in patients undergoing EI due to COVID-19-related respiratory distress syndrome is a matter of concern. There are few reports in the literature on the management of COVID-19-related tracheal complications. In the present study, we aimed to compare the early results of surgical treatment of complex PITS in patients with a history of intensive care unit (ICU) admission and EI due to severe COVID-19 and those with EI due to other benign etiologies.

Patients and Methods

Setting and Study Population

Our study was designed as a descriptive and cross-sectional study and approved by the local ethics committee (E1-21–1788). We evaluated a total of 15 patients who underwent tracheal resection and reconstruction (TRR) due to complex PITS between March 2020 and April 2021 in a tertiary center. All 15 patients had a history of ICU admission and mechanical ventilation via EI. Seven patients (46.6%) were grouped as COVID-19 and eight patients (53.4%) non-COVID-19, depending on whether the EI was due to respiratory failure resulting from SARS-CoV-2 infection or not. We excluded patients who underwent TRR due to tracheoesophageal fistula, tracheal malignancy, and blunt or penetrating tracheal trauma. All patients in the COVID-19 group had SARS-CoV-2 reverse transcriptase polymerase chain reaction (RT-PCR) positivity along with clinical and radiological compatibility. Our investigation involved data obtained from physical and digital hospital records.

We analyzed the patients' age, gender, concomitant diseases, reason of EI, duration of EI, reason of tracheostomy, symptoms, time from tracheal trauma to diagnosis, history of bronchoscopic intervention (dilatation, stent placement), surgical information, postoperative complications, and duration of follow-up. We assumed the date of EI as the time to onset of tracheal trauma.

The same radiologist evaluated pre-operative computed tomography (CT) of the neck and thorax with sagittal and coronal reconstruction (0.625-mm slice thickness) in all patients. (Fig. 1) In the process, the trachea was radiologically divided into 3 equal segments, and the stenosis was classified as upper, middle, or lower tracheal depending on where most of it was located. Stenotic tracheal segment lengths were measured and recorded in millimeters. In the preoperative period, all patients underwent rigid bronchoscopy to determine the nature of stenosis, evaluate mucosal inflammation, and classify stenosis. We graded the tracheal stenosis using the Cotton-Myer classification system (grade I: < 50%, grade II: 51–70%, grade III: 71–99%, and grade IV: no detectable lumen) [9].

First, a surgeon wearing complete personal protective equipment (PPE) (N95 mask, hood, face shield, coveralls, gloves) performed bronchoscopic intervention (mechanical

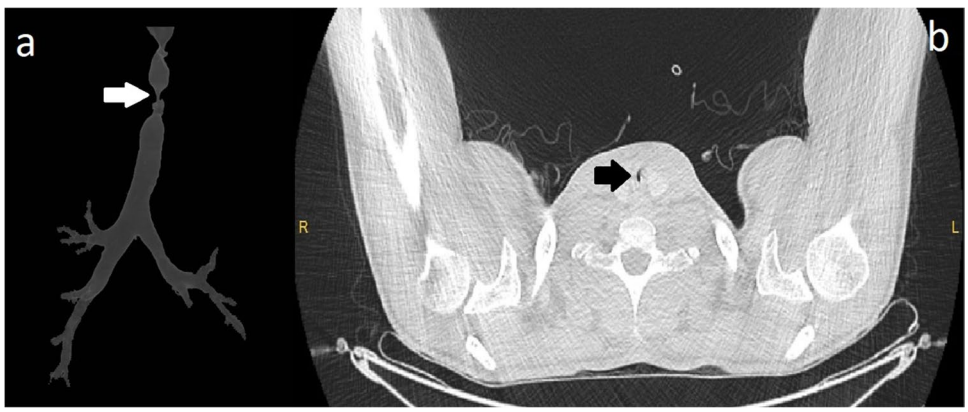

Fig. 1 Computed tomographic view of the tracheal stenosis. **a** 3-Dimensional reformation of the trachea. The narrowest tracheal segment was marked with a white arrow. **b** Axial plain computed tomography reveals the narrowest tracheal segment (marked with black arrow). The patient was relieved symptomatically with tracheal dilatation, and then, elective tracheal resection and reconstruction was performed

dilatation) in the patients with severe respiratory distress and provided symptomatic relief. Then, after allowing time to reduce mucosal inflammation in the trachea and the maturation of stenosis, elective surgery was performed. The number of bronchoscopic intervention sessions was recorded.

All operations took place during the COVID-19 pandemic. Before each operation, two combined oropharyngeal and nasopharyngeal swab samples were taken from the patients 48 h apart for SARS-CoV-2 RT-PCR testing. Patients with negative results underwent surgery. The procedures were conducted with minimal staff in full PPE. Combined oropharyngeal and nasopharyngeal swab samples were taken for RT-PCR testing on the fifth and seventh postoperative days from the surgical team who participated in the operations in the COVID-19 group.

We used total intravenous anesthesia in all operations. The dose of the neuromuscular blocking agent was optimized to prevent reactions in patients such as gagging and straining that will provoke aerosol formation in the upper respiratory tract. In patients with advanced tracheal stenosis, bronchoscopic dilatation was performed immediately before the operation to allow the passage of endotracheal tube size 6.5. In patients who could not be weaned from the tracheostomy, the airway was managed through the tube. We performed the operations through a cervical collar incision. When the stenosis was mid-tracheal or collar incision was insufficient, an incision was made from the midline to the jugular notch without sternotomy (Fig. 2a). Tracheal needle puncture was applied with fiberoptic bronchoscopy to determine the stenotic segment boundaries during the operation accurately (Fig. 2b). We thus identified the precise craniocaudal boundaries of the stenotic segment and marked them with suture material to the anterior wall of the trachea. Only the stenotic segment of the trachea was wholly released, and the cartilaginous rings in the stenotic segment were excised together with the membranous surface (Fig. 2c). We intubated the distal trachea with a size 6/6.5 tube (with a size 5 cuff in a pediatric patient) and provided cross-field ventilation through a sterile connection tube. In order to minimize the risk of airborne transmission during the operation of the COVID-19 patients, the operations were resumed at apneic periods when the trachea was open. Tracheal reconstruction was performed with 3/0 absorbable monofilament sutures using the continuous technique. In order to reduce the tension on the anastomotic line, supporting sutures were placed on both cartilaginous-membranous corners of the proximal and distal trachea with 2/0 absorbable multifilament suture material (Fig. 2d). No release maneuver was required because the resected tracheal segments were shorter than four cm.

The patients were extubated in the operating room. Before extubation, glycopyrrolate was administered to reduce oral secretion in COVID-19 patients and prevent viral transmission. Topical lidocaine was applied to the oropharyngeal region to suppress the cough reflex after extubation. A single dose of

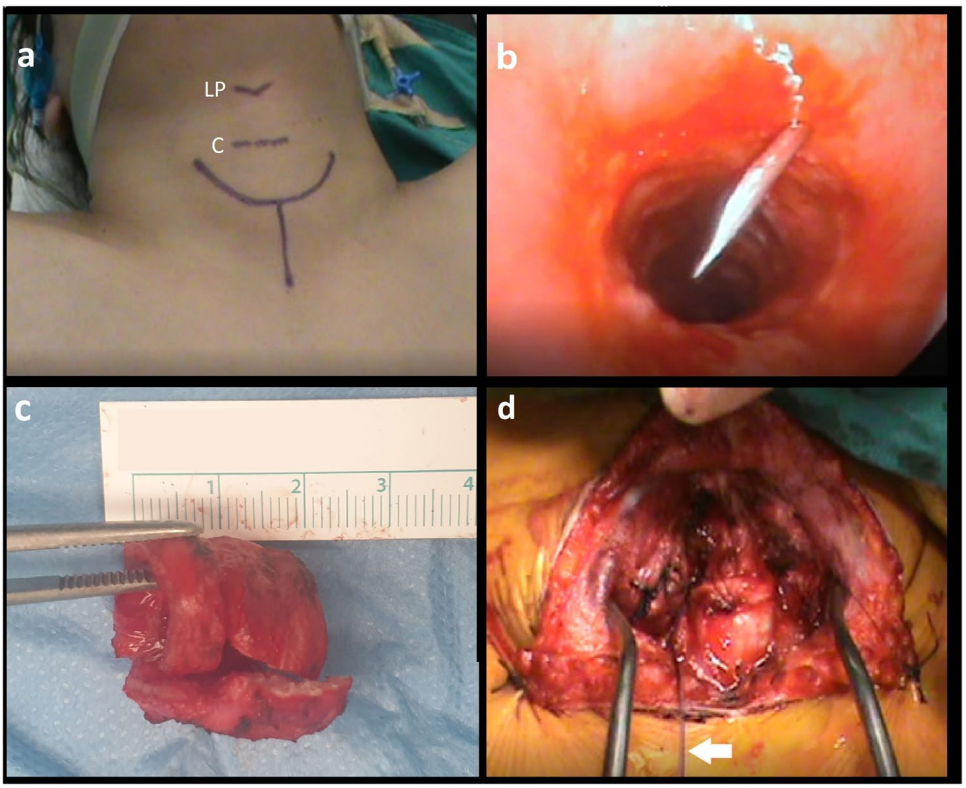

Fig. 2 Images of post-intubation tracheal stenosis surgery. **a** The appearance of a collar incision where a vertical incision will be inserted towards the jugular notch when the head is in semi-extension (LP: laryngeal prominence, C: cricoid cartilage). **b** Tracheal puncture for precise determination of stenosis margins, accompanied by bronchoscopy. **c** Appearance of resected tracheal segment, **d** Final view of the tracheal anastomosis line (lateral support suture is marked with white arrow)

1 mg/kg methylprednisolone was administered to patients to prevent postoperative laryngeal edema.

A chin-sternum suture was placed with semi-flexed positioning of the head to avoid hyperextension of the neck. Type of anastomosis (cricoid-to-tracheal, or end-to-end tracheal), amount of bleeding, operating time, postoperative complications, and length of hospital stay were recorded. We assessed postoperative complications as minor (grades I and II) or major (grades III and IV) according to the Clavien-Dindo classification of surgical complications [10]. We also classified them into two categories: anastomotic and non-anastomotic. The former consisted of granulation tissue formation, restenosis, all kinds of anastomotic dehiscence, and fistula formation. The latter category included laryngeal edema, swallowing disorder, dysphonia, wound infection, pneumonia, and arrhythmia. We followed up the patients weekly in the postoperative first month and monthly after that, and all for at least six weeks. At the end of the first month, all patients underwent fiberoptic bronchoscopy to verify the safety of the anastomosis. Thoracic CT was performed in patients with respiratory distress, wheezing or stridor findings, or narrowing of the air column on direct X-ray. In postoperative follow-ups, we considered complaints of dyspnea during daily activity as "failed" and during exercise as "satisfactory," and no dyspnea during exercise as "excellent" outcomes. We regarded only the latter two categories successful.

Statistical Analysis

We used IBM SPSS Statistics for Windows, Version 22.0 (SPSS Inc., Chicago, IL, USA) for statistical analysis. Descriptive statistics are given with frequency and percentage for categorical variables and mean and standard deviation (median and range) for quantitative variables. We checked normality using the Shapiro–Wilk test. In subsets, we conducted univariate analyses using the chi-square and Mann–Whitney *U* tests. A $p < 0.05$ was considered statistically significant.

Results

15 patients underwent TRR due to PITS. Six of these were woman (40%), and 9 (60%) were men. Their mean age was 43.3 SD 20.5 (median: 38, range: 12–76). Table 1 shows the demographic data of the patients.

The mean EI duration was 21.0 SD 4.04 days (median: 16, min–max: 14–28) in the COVID-19 group and 12.0 ± 1.15 (median: 12.5, min–max: 10–16) in the non-COVID-19 group. A statistically significant difference was found between the groups in terms of EI duration ($p = 0.014$). The time from tracheal trauma (EI) to symptom onset was 42.0 ± 1.15 days in the COVID-19 group, and 39.3 ± 1.85 days in the non-COVID-19 group ($p = 0.152$). (Table 2).

On CT images, the mean stenotic segment length was 20.3 SD 2.7 mm (median: 18, range: 12.5–32.5) in the COVID-19 group, and 16.3 ± 0.8 mm (median: 16, range: 13.7–18.7) in the non-COVID-19 group ($p = 0.613$). The bronchoscopic and radiological features of the patients are shown in Table 3.

The bronchoscopic intervention could not be performed in 3 patients (20%) due to severe stenosis (> 90% of the tracheal lumen), whereas 12 patients (80%) underwent bronchoscopic dilatation. The median number of dilatation sessions was 3 (min–max: 2–4). The time between dilatation sessions was 30.6 SD 3.38 days in the COVID-19 group and 35.5 SD 2.19 days in the non-COVID-19 group. There was no statistically significant difference between the groups in that respect ($p = 0.189$). A silicone Y stent was previously placed in another center to one of the patients (6.6%). The silicone stent was removed 1 week after application because of the migration.

The patients underwent TRR 129.5 SD 15.03 days (median: 117, min–max: 87–201) after tracheal injury in the COVID-19 group, and 134.3 SD 15.04 days (median: 135, min–max: 71–192) in the non-COVID-19 group. There was no statistically significant difference between the groups in terms of time from tracheal trauma to operation ($p = 0.867$) (Table 2). Operative data by groups are shown in Table 4. Trachea-to-trachea anastomosis was performed on all patients in the COVID-19 group. Two (25%) patients in the non-COVID-19 group underwent cricoid-to-tracheal anastomosis. The resected tracheal segment lengths according to the groups are given in Fig. 3.

Postoperative minor complications were developed at 6 patients (40%). Wound infection developed in 2 patients (13.3%), bacterial pneumonia in 2 patients (13.3%), arrhythmia in 1 patient (13.3%), and granulation tissue formation on the anastomotic line in 1 patient (6.6%). 3 patient (42.9%) developed non-anastomotic complication in the COVID-19 group ($n = 7$), and 2 patients (25%) non-anastomotic and 1 patient (12.5%) anastomotic complication (granulation tissue formation) in the non-COVID-19 group ($n = 8$). The patient with anastomotic complication had a symptom of dyspnea on exercise and an invasive procedure did not required. There was no statistically significant difference between the groups regarding the distribution of postoperative complications ($p = 0.713$). The mean length of hospital stay was 11.0 SD 3.51 days in the COVID-19 group and 7.0 SD 2.51 days in the non-COVID-19 group ($p = 0.779$).

The mean postoperative duration of follow-up was 10.71 SD 0.28 months in the COVID-19 group and 15.0 SD 1.48 months in the non-COVID-19 group. The difference between the groups was statistically significant ($p = 0.022$). The operation outcome was "excellent" in all patients in the

Table 1 Baseline characteristics of patients

Baseline characteristic	COVID-19		Non-COVID-19		Full sample	
	n	%	*n*	%	*N*	%
Gender						
Female	3	42.9	3	37.5	6	40
Male	4	57.1	5	62.5	9	60
Co-morbidity						
DM	3	42.9	3	37.5	6	40
HT	3	42.9	2	25.0	5	33.3
COPD	3	42.9	-	-	3	20
Cardiomyopathy	-	-	1	12.5	1	6.7
None	2	28.6	3	37.5	5	33.3
Symptom						
Dyspnea	2	28.6	4	50	6	40
Stridor	3	42.9	3	37.5	6	40
Inability to wean tracheostomy	2	28.6	1	12.5	3	20
IMV etiology						
RDS due to COVID-19	7	100	-	-	7	46.6
SAH	-	-	2	25	2	13.3
CVA	-	-	2	25	2	13.3
CCHF	-	-	1	12.5	1	6.7
Drug intoxication	-	-	1	12.5	1	6.7
Hearth failure	-	-	1	12.5	1	6.7
Pneumonia after CABG	-	-	1	12.5	1	6.7
Tracheostomy						
None	4	57.1	5	62.5	9	60
Prolonged IMV	1	14.3	2	25.0	3	20
Urgent	2	28.6	1	12.5	3	20

Participants were on average 43.3 years old (*SD* = 20.5)

DM diabetes mellitus, *HT* hypertension, *COPD* chronic obstructive pulmonary disease, *IMV* invasive mechanical ventilation, *RDS* respiratory distress syndrome, *SAH* subarachnoid hemorrhage, *CVA* cerebro vascular accident, *CCHF* Crimean-Congo hemorrhagic fever, *CABG* coronary artery by-pass grafting surgery

Table 2 Time to endotracheal intubation, symptom onset, and surgery by groups

Variables (days)	COVID-19		Non-COVID-19		*P* value
	M	*SD*	*M*	*SD*	
Intubation duration	21.0	4.04	12.0	1.15	.014
Time from tracheal trauma to symptom onset	42.0	1.15	39.3	1.85	.152
Dilatation interval	30.6	3.38	35.5	2.19	.189
Time from tracheal trauma to surgery	129.5	15.0	134.3	15.0	.867

COVID-19 group, and "satisfactory" in 1 patient (12.5%), and "excellent" in 7 patients (87.5%) in the non-COVID-19 group. We regarded all outcomes successful. No SARS-CoV-2 cross-infection occurred in the staff participating in the operation of COVID-19 patients.

Discussion

The present study is one of the few in the literature to report the management of COVID-19-related post-intubated tracheal stenosis and the early results of surgical treatment. Our investigation yielded no statistically significant difference between COVID-19- and non-COVID-19-related PITS patients in terms of presenting symptoms, time from tracheal trauma to symptom onset, stenosis location, stenosis severity, length of the stenotic segment, number of bronchoscopic dilatation sessions, dilatation time intervals, intra-operative features, length of the resected tracheal segment, post-operative complications, and length of post-operative hospital stay.

Table 3 Radiological and bronchoscopic features of patients' tracheal stenosis

Variables	COVID-19		Non-COVID-19		Full sample	
	n	%	*n*	%	*N*	%
Stenosis location on thorax CT						
Upper 1/3 trachea	7	100	4	50	11	73.3
Middle 1/3 trachea	-	-	4	50	4	26.7
Myer-Cotton stenosis grade						
2	2	28.6	4	50	6	40
3	5	71.4	4	50	9	60
Bronchoscopic dilatation						
Yes	5	71.4	7	87.5	12	80
No	2	28.6	1	12.5	3	20
Stent application						
Yes	-	-	1	12.5	1	6.7
No	7	100	7	87.5	14	93.3

Table 4 Operative information, hospitalization, and post-operative follow-up time by groups

Variables	COVID-19		Non-COVID-19		*P* value
	M	*SD*	*M*	*SD*	
Operation duration (min)	175.6	8.29	186.6	12.0	.536
Operative blood loss (ml)	135.0	13.2	133.3	24.0	.463
Resected segment (mm)	30.66	2.96	28.6	1.85	.536
LOS (day)	11.0	3.51	8.66	0.66	.779
Follow-up (month)	10.71	0.28	15.0	1.48	.022

LOS length of hospital stay, *min* minute, *mm* millimeter, *ml* milliliter

In PITS, the patient may not develop any symptoms until a severe narrowing of the tracheal lumen occurs. Fifty percent of stenosis causes only dyspnea during exercise, while more than 50% manifests with dyspnea and stridor at rest [11, 12]. Early symptoms of tracheal stenosis, such as coughing and dyspnea during exercise, may be confused with the recovery from pneumonia or with diseases such as asthma and COPD. COVID-19-related PITS is also likely to be diagnosed late, as it can be masked by coughing and dyspnea during exercise that persists throughout COVID-19 recovery. In 10 (66.6%) of the 15 patients included in the present study, the presenting symptom was dyspnea or stridor at rest, indicating severe tracheal stenosis.

Intubation duration was found to be statistically significantly longer in the COVID-19 group in current study. This difference may be due to lung damage and hyper-inflammation status due to COVID-19, or overlapping infections. It may also be because healthcare professionals are prone to prolonged intubation due to aerosol formation. In addition, it is possible to experience disruptions in intensive care nursing services due to the increased workload of the COVID-19 pandemic. PITS can be avoided almost entirely by choosing the appropriate endotracheal tube for each patient and intermittent cuff pressure monitoring. Tracheal complications due to prolonged intubation are likely to be common in COVID-19 patients due to worsening intensive care services. Tracheal complication rates in COVID-19 patients need to be evaluated with further studies.

PITS occurs approximately 4 to 6 weeks after tracheal trauma. A study of 117 PITS cases by Shin et al. reported that the meantime from tracheal trauma to diagnosis was 1.8 (1.1–3) months [13]. Similarly, in our study, the time to diagnosis was 42.0 ± 1.15 days in the COVID-19 group and no statistically significant difference was found between the non-COVID-19 groups.

The recurrence rate after bronchoscopic dilatation is reported to be 90%, and failure of TRR 10%, in complex PITS patients [14]. Bronchoscopic balloon or mechanical dilatation should only be used as a bridge to surgical treatment in symptomatic patients. In our study, mechanical dilatation was performed in 12 patients (80%), whereas 3 patients (20%) with severe (> 90%) stenosis could not undergo the procedure. Tracheal dilatation was performed for a minimum of 2 and a maximum of 4 sessions due to symptomatic tracheal stenosis. Recurrence developed in all patients who underwent mechanical tracheal dilatation [15–17].

Several investigators recommend allowing time to reduce the inflammation in the trachea and ensure the maturation of the stenosis before surgery in PITS patients [18, 19]. This period varies by center. We take account of the interval between dilatation sessions as a basis in our clinic [7]. Chondronecrosis foci formed in the PITS area cause cartilage ring breaks over time. Thus, the ongoing mucosal and submucosal inflammation in the stenotic segment contributes to narrowing the lumen in the acute period, causing symptoms at more frequent intervals in the trachea with a collapsed roof. As a result, we believe that the time elapsed between

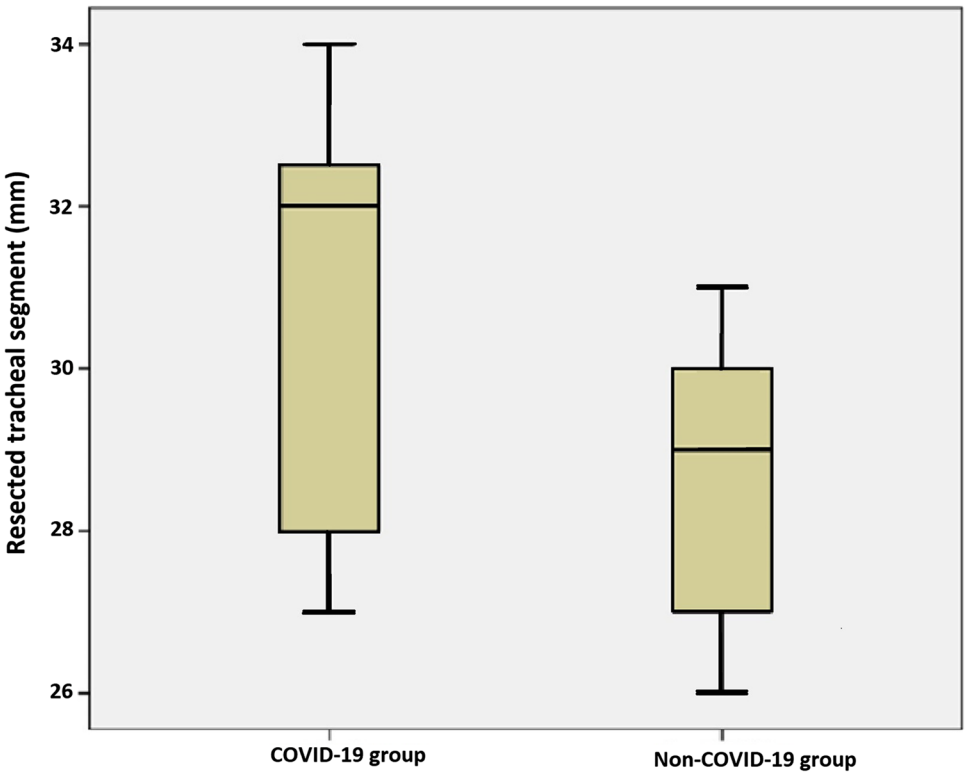

Fig. 3 Group distribution plot of resected tracheal segment lengths. The resected tracheal segment lengths are shown as a box plot in millimeter according to the COVID-19 and non-COVID-19 groups

tracheal dilatation and the recurrence of symptomatic stenosis is decisive for surgery. We generally plan surgery if the time between the dilatation sessions is less than 2 weeks.

Patients presenting with tracheostomy are not rare in PITS. Tracheostomy can be performed electively due to prolonged ventilation or urgently due to acute respiratory distress. The procedure has specific and complex tracheal complications. EI may entail tracheal trauma due to high ETT cuff pressure and tube size, whereas tracheostomy may induce trauma related to a stoma, cannula size, cuff pressure, or cannula tip [11, 13]. In PITS patients, it is recommended to remove the tracheostomy by providing dilatation if possible and wait to reduce mucosal inflammation before performing TRR [19, 20]. Airway colonization and local inflammation due to tracheostomy may increase the risk of postoperative infection [20]. In fact, most patients with complex PITS can be managed with bronchoscopic dilatation if early diagnosed. Although PITS patients typically have dramatic respiratory failure at presentation, mucosal inflammation and tracheal secretion can be reduced with medical treatment, providing partial symptomatic relief. Patients should be transferred to a center for the bronchoscopic procedure subsequently, for preventing complications secondary to emergency tracheostomy. In our study, three patients with tracheostomies could be decannulated using tracheal dilatation.

Previous studies have reported that 50% of the trachea can be resected in adults and 30% in pediatric patients [19]. Wright et al. indicated that the risk of anastomotic complications increased two-folds when the resected segments exceed 4 cm [18]. Reduced tracheal mobility due to kyphosis and tracheal calcification in elderly patients, who also constitute most of the ICU population, causes an increased anastomotic tension independent of the resected segment. The mean tracheal segment length resected in the patients in our study was less than 4 cm. A tracheal release maneuver was not needed because anastomotic line tension was not high.

Despite being the gold standard in the treatment of complex PITS, TRR causes significant morbidity and mortality. Various studies have reported TRR complication rates between 15 and 45% [20–22]. Wright et al. reported an 18% major complication and 9% anastomotic complication rates in their study on 901 tracheal resection cases [20]. In our study, minor complications developed in 6 patients (40%), and only one of these was granulation tissue formation at anastomosis site. We think there are two main reasons for the low rate of anastomotic complications in our cases. First, the patients underwent operation without applications such as stent placement and prolonged and complicated tracheostomy that potentially cause secondary granulation or stenosis. So, we performed TRR for tracheal injuries within the ETT cuff injury limits. Second, our surgical technique involved continuous sutures combined with support sutures to reduce tension at anastomotic edges, rendering the anastomosis safer and leading to better outcomes.

Our study's retrospective design and small sample size are among its limitations. However, tracheal resection and reconstruction are performed in low numbers in many centers. In a multicenter study in which Stanifer et al. analyzed 1167 cases of tracheal resection and reconstruction, they reported that the annual number of operations was less than 4 in 91.6% of the centers [23].

Conclusion

Trachea resection and reconstruction can be performed safely and successfully in patients with COVID-19-related complex PITS. Comprehensive preoperative examination and planning, appropriate selection of surgery technique, and close postoperative follow-up significantly reduce complications. Laryngotracheal complications may develop after discharge in patients that had stayed in ICU due to severe COVID-19. Patients with PITS should be referred to centers experienced in tracheal surgery.

Declarations

This study was approved by local ethic committee (approval number E1-21–1788).

Conflict of Interest The authors declare no competing interests.

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