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# A Study on the Prevalence of Laryngeal Injuries and Dysphagia in Critically Ill Tracheostomized Patients due to COVID-19

## *Estudio de prevalencia de lesiones laríngeas y disfagia en pacientes críticos traqueostomizados por COVID-19*

Falduti, Alejandra K[1]; Chiappero, Guillermo R[1]; Catini, María Eugenia[1]

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**Correspondence**
Alejandra Falduti, alejandrafalduti13@gmail.com; Zelada 4424, CABA, Argentina, CP 1407

## ABSTRACT

**Introduction:** Patients with severe pneumonia due to COVID-19 may require orotracheal intubation, prolonged mechanical ventilation and tracheostomy. The presence of an artificial airway can generate laryngeal lesions and it is associated with swallowing dysfunction and increased risk of aspiration.
**Objective:** The main objective of this study is to describe the prevalence of laryngeal lesions and oropharyngeal dysphagia in critically ill tracheostomized patients due to COVID-19. As a secondary objective, is to evaluate the association between the presence of laryngeal injury and dysphagia and each of them with other variables related to the patient's history, duration of the artificial airway and the prone position maneuver.
**Methods:** This is an observational, longitudinal and retrospective study, conducted at the Juan A Fernández Hospital, CABA, Argentina. Tracheostomized patients diagnosed with COVID-19 were consecutively included. The presence of laryngeal lesions and dysphagia was recorded by fibroscopic evaluation of swallowing at the time of decannulation.
**Results:** 32 patients were analyzed, of which 28 (87.5%) showed at least one laryngeal lesion, mainly in the glottic region. The prevalence of dysphagia was 65.6% (21/32). No significant association was found between laryngeal injuries and dysphagia ($p = 0.70$).
**Conclusion:** laryngeal injuries and dysphagia were highly prevalent in this cohort of patients. The early evaluation through fibroscopic evaluation of swallowing for the protocolized follow-up of these patients, has provided us a timely diagnosis to guide treatment individually until decannulation and resolution of the dysphagia found.

**Key words:** Covid19; Decannulation; Swallowing; Dysphagia; Laryngeal Injury

## RESUMEN

**Introducción:** Los pacientes con neumonía grave por COVID-19 pueden requerir intubación orotraqueal, ventilación mecánica prolongada y traqueostomía. La presencia de la vía aérea artificial puede generar lesiones laríngeas y estar asociada a disfunción deglutoria con aumento del riesgo de aspiración.

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[1]Hospital Juan A. Fernández, Av. Cerviño 3356, Autonomous City of Buenos Aires (CABA), C1425, Argentina.

**Objetivo:** Describir la prevalencia de lesiones laríngeas y disfagia orofaríngea en los pacientes críticos traqueostomizados por COVID-19. Como objetivo secundario, evaluar la asociación entre la presencia de lesión laríngea y disfagia y de cada una de ellas con antecedentes del paciente, duración de la vía aérea artificial y maniobra de decúbito prono.

**Material y métodos:** Estudio observacional, longitudinal y retrospectivo, realizado en el hospital Juan A. Fernández, CABA, Argentina. Se incluyeron de manera consecutiva pacientes con diagnóstico de COVID-19 traqueostomizados. La presencia de lesiones laríngeas y disfagia se valoró mediante estudio endoscópico de la deglución al momento de la decanulación.

**Resultados:** Se analizaron 32 pacientes, de los cuales, 28 (87,5%) evidenciaron al menos una lesión laríngea, principalmente en la región glótica. La prevalencia de disfagia fue de 65,6% (21/32). No se encontró asociación significativa entre lesiones laríngeas y disfagia (p = 0,70).

**Conclusión:** En esta cohorte de pacientes, las lesiones laríngeas y la disfagia fueron altamente prevalentes. La evaluación precoz mediante endoscopia de la deglución nos ha facilitado un diagnóstico oportuno para guiar el tratamiento de manera individual hasta la decanulación y resolución de la disfagia encontrada.

**Palabras claves:** Covid-19; Decanulación; Deglución; Disfagia; Lesiones laríngeas

## INTRODUCTION

At the end of 2019, in the city of Wuhan, China, a new beta coronavirus was identified, the SARS-CoV 2, finally called coronavirus disease 2019 (COVID-19). The World Health organization (WHO) declared it a pandemic on March 11th, 2020.[1-3]

The predominant finding in a seriously ill patient is acute hypoxemic respiratory failure due to acute respiratory distress syndrome (ARDS), and the patient may need to be admitted to the Intensive Care Unit (ICU).[4]

At the beginning of the pandemic, one in five infected persons was hospitalized; one in ten could be admitted to the ICU and most of these patients required orotracheal intubation (OTI) and had to be connected to invasive mechanical ventilation (IMV).[5] Prolonged OTI can cause laryngeal injuries that impact on the function of the upper airway, alter its permeability, and cause voice or swallowing disorders. These injuries can be detected after extubation and sometimes require tracheostomy (TQT).[6-8] Having OTI for more than 7 days increases the degree of the laryngeal injury, according to the duration of the intubation, the size of the endotracheal tube, the general condition of the patient, and the presence of infection.[9]

In these cases, the prone position maneuver was used as treatment of ARDS. The effect of this maneuver over the larynx and the pharynx hasn't been studied yet, but it is believed that it could determine laryngeal and upper airway edema.[8]

Patients with prolonged IMV require TQT. Williams et al.[10] reported that TQT rates during the coronavirus pandemic varied significantly, from 16% to 61%, but were higher than pre-pandemic rates. The SATICOVID study reported that one quarter of the patients who had received IMV were tracheostomized.[3] The TQT is a risk factor for swallowing disorder, and up to 50% of these patients show risk of aspiration. The presence of the TQT cannula causes the translaryngeal airflow to cease, thus causing desensitization of the laryngopharynx, lack of coordination of the glottic closure, and disuse atrophy of the muscles involved in the swallowing process, which may cause dysphagia.[8]

There isn't much information yet about the frequency of laryngeal injuries and dysphagia in this population.[11] The main objective of this study was to describe the prevalence of laryngeal injuries and oropharyngeal dysphagia at the time of decannulation in patients who required TQT after receiving prolonged mechanical ventilation secondary to COVID-19. The secondary objective was to evaluate the association between the presence of laryngeal injuries and dysphagia and of each one of them with other variables related to

the patient's medical history, the duration of the artificial airway (AAW) and the decubitus prone position maneuver.

## MATERIALS AND METHODS

The following study was conducted in the Hospital General de Agudos Dr. Juan Antonio Fernández (HGAJAF), Autonomous City of Buenos Aires (CABA), Argentina, in the period between July, 2020 and December, 2020. The study was retrospective, cross-sectional and observational.

It included consecutive patients older than 18 years hospitalized at the HGAJAF who had been diagnosed with COVID-19 upon hospital admission, had required OTI and IMV for more than 72 hours, and were tracheostomized and weaned from IMV or going through the weaning process.

The following demographic and clinical data were recorded: age, sex, personal history, duration of sedation, analgesia, and neuromuscular blockade. Regarding the IMV and AAW, we recorded the following: OTI and TQT dates, IMV start and end dates, the need to reintubate and number of prone cycles. Also, the days of ICU stay and hospital stay were recorded.

At the beginning and during the decannulation process, we evaluated the following: the degree of agitation and sedation through the Richmond Agitation and Sedation Scale (RASS); the delirium acquired at the ICU, with the CAM-ICU tool (Confusion Assessment Method for the Intensive Care Unit); the maximum expiratory pressure, and the peripheral muscle strength, through the Medical Research Council scale (MRC). The blue staining test was done and we recorded the first evaluation made when the patient was breathing spontaneously without ventilatory support for 24 hours; also the peak cough flow was measured.

The Fiberoptic Endoscopic Evaluation of Swallowing (FEES) was carried out in patients who presented altered permeability of the AW during the decannulation process, or those who tolerated occlusion of the TQT cannula for 24 hours or upon the physician's request for the assessment of the AW or the swallowing ability.

The study was carried out by an intensive care physician and a kinesiologist, with flexible videoscope (Ambu® aScope™). First, the study evaluated the anatomical structures, the mobility of the vocal cords and glottic closure; then, the sensitivity was assessed, by touching the epiglottis, the arytenoid folds, and vocal cords with the tip of the endoscope. The Murray scale was used[7] for the assessment of the saliva (Appendix A), for which a score of 3 was considered as risk of aspiration. Then, semi-solid food was administered in three different volumes, and blue liquid in 5 mL, 10 mL and 15 mL, and the patient was evaluated with the Penetration-Aspiration Scale (PAS)[12] (Appendix B).

The existence of laryngeal injuries, the Murray saliva score and the PAS scale were also recorded. A PAS score ≥ 2 points was considered as dysphagia for each consistency. Some patients couldn't complete the test with food due to a high risk of aspiration, difficulty in swallowing maneuvers or because they didn't understand the task.

To finish the study, the transtracheostomy evaluation was carried out. After removing the TQT cannula, the endoscope was introduced through the ostomy in the cephalic direction with the tip directed towards the subglottic region; this region and the lower side of the vocal cords were observed. The presence of sub-glottic injuries was assessed, and the patient was administered blue liquid in order to observe the presence of aspiration.

The study was recorded to be subsequently analyzed by the evaluation team. Data were registered in a database for subsequent analysis.

## STATISTICAL ANALYSIS

The data were considered as nonparametric due to the small sample size, and are reported with median and interquartile range (IQR), if numerical, and with the absolute number of presentation and percentage, if categorical. Two groups were created taking into account the presence or absence of clinically evaluated dysphagia. Also a subanalysis was conducted in patients who received the instrumental evaluation of the AW through the FEES, and were categorized according to the presence or absence of laryngeal injuries. We used the Fisher's Exact Test to compare the categorical variables. And for the comparison of continuous variables, we used the Mann Whitney Test. A $p$ value of $\leq 0.05$ was considered significant. For the data analysis, we used the IBM SPSS Macintosh software version 24.0 (IBM Corp., Armonk, NY, USA).

## RESULTS

### Sample characteristics

A total of 39 tracheostomized patients on IMV due to COVID-19 were included in the study. Four of those patients were excluded for the following reasons: three patients showed infectious complications and died, and the other one was excluded due to data loss.

Three (9.4%) out of the 35 subjects couldn't be evaluated with the FEES (for logistic reasons) and were removed from this subanalysis.

### Demographic, clinical and ICU stay-related variables

8 (22.9%) of the 35 patients included in the study were female, and the median of age was 57 years (IQR 49-66). Arterial hypertension and obesity were the most prevalent comorbidities.

Regarding the medication administered during the ICU stay, all the patients required analgesia and sedation with a median of 28 d (IQR 20-37.5) and 24 d (IQR 16.7-31.2), respectively. Thirty three (94.3%) patients required neuromuscular blocking

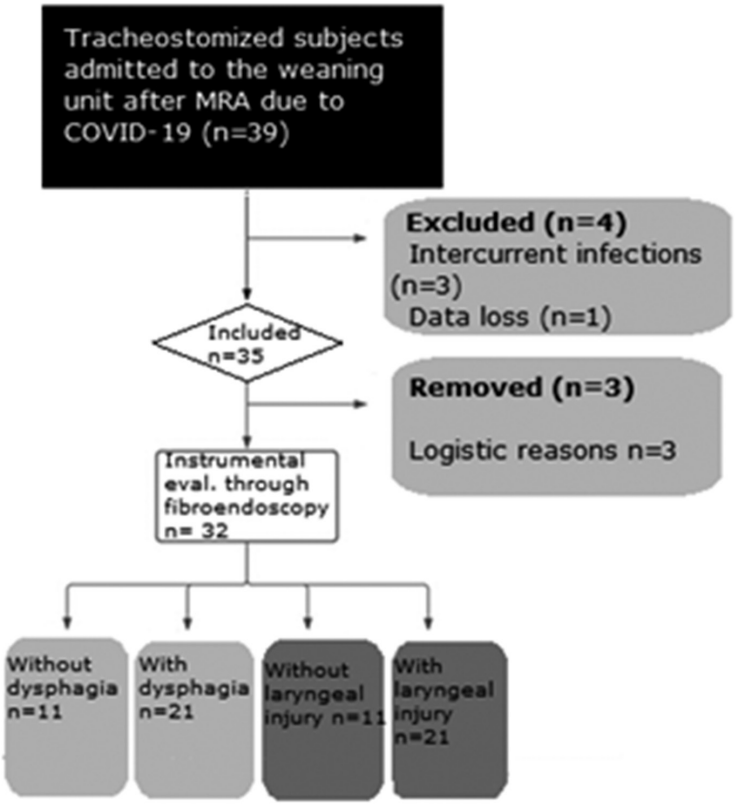


**Figure 1.** Flow diagram of the participants.

agents and antipsychotics with a median of 8 d (IQR 6-15) and 29 d (IQR 19.5-44), respectively. Thirty subjects (85.7%) required inotropic drugs with a median of 8.5 days (IQR 3.7-13.2).

19 (54.3%) of the total sample subjects required the decubitus prone position as rescue maneuver. 7 of them (36.8%) received only one cycle of decubitus prone; 5 (26.3%) received two cycles, and 7 (36.8%) had three or more cycles.

### Instrumental evaluation: FEES (*n* = 32)

Before decannulation, and after 24 hours of occlusion of the tracheostomy cannula or use of the phonatory valve, the FEES was carried out.

### Prevalence and characteristics of the laryngeal injuries

As regards the existence and types of laryngeal injuries, 28 (87.5%) of the 32 patients showed at least one injury. 21 (75%) of them ($n$ = 28) showed only one injury; 6 (21.4%), two injuries, and 2 (7.1%) showed three injuries. Three patients weren't able to complete the evaluation of the subglottic region because they couldn't tolerate the procedure. 39 injuries were registered [$n$ = 21 (75%)], followed by paresis/unilateral vocal cord paralysis [$n$ = 10 (35.7%)] and incomplete glottic closure [$n$ = 6 (21.4%)] (Table 2).

### Factors associated with laryngeal injuries

For the purpose of evaluating the association between the presence of laryngeal injuries and other variables, the 32 subjects under evaluation were divided in two groups: "without laryngeal injury" [$n$ = 11 (34.4%)] and "with laryngeal injury" [$n$ = 21 (65.6%)]. The "without laryngeal injury" group included patients who didn't have any injuries in the larynx or an ulcer in the posterior commissure, which was considered a mild injury with no clinical implication.

The presence of diabetes was more prevalent in patients without laryngeal injury [4/11; (36.4%)] compared to the group with laryngeal injury [(1/21; (4.8%)]. This association was statistically

**TABLE 1.** Sample characteristics

| Variables | n = 35 |
|---|---|
| Females n (%) | 8 (22.9) |
| Age, median (IQR), years 57 (49-66) | 57 (49-66) |
| Apache II, median (IQR), score | 15.5 (10-23.5) |
| SOFA, median (IQR), score | 6 (4-9) |
| *Medical history, n (%)* | |
| Hypertension | 7 (20) |
| Cardiac | 1 (2.9) |
| Respiratory | 3 (8.6) |
| Neurologic | 1 (2.9) |
| Diabetes | 5 (14.3) |
| Obesity | 8 (22.9) |
| Psychiatric | 1 (2.9) |
| *Medication, n (%)* | |
| Analgesia) | 35 (100) |
| Sedation | 35 (100) |
| NMBAs | 33 (94.3) |
| Antipsychotics | 33 (94.3) |
| Inotropic drugs | 30 (85.7) |
| RASS, median (IQR), score | 0 (0-0) |
| Decubitus prone position, n (%) | 19 (54.3) |
| ETT exchange required, n (%) | 7 (20) |
| Days of OTI, median (IQR) | 17 (19-21) |
| Days of IMV, median (IQR) | 40 (30.5-48.5) |

References. IQR (interquartile range); Apache II (Acute Physiology and Chronic Health Disease Classification System); SOFA (Sepsis Related Organ Failure Assessment); NMBAs (neuromuscular blocking agents); RASS (Richmond Agitation Sedation Scale); ETT (endotracheal tube); OTI (orotracheal intubation); IMV (invasive mechanical ventilation).

**TABLE 2.** Characteristics of laryngeal injuries (*)

| Variables | Laryngeal injuries (n = 39 |
|---|---|
| *Supraglottic injury, n (%)* | 4 (14.2) |
| Collapse | 4 (14.2) |
| *Glottic injury, n (%)* | 28 (87.5) |
| Ulcers in posterior commissure | 21 (75) |
| Arytenoid edema | 4 (14.2) |
| Arytenoid subluxation | 1 (3.5) |
| Paresia or unilateral VC paralysis | 10 (35.7) |
| Incomplete glottic closure | 6 (21.4) |
| *Subglottic injury, n (%)* | 7 (25) |
| Edema | 2 (7.1) |
| Granuloma | 2 (7.1) |
| Collapse | 3 (10.7) |

References. VC (vocal cords)
*Each subject could have shown more than one laryngeal injury, so he/she could be included in more than one category.

significant ($p = 0.03$). When we compared the presence of laryngeal injuries with the rest of the variables, we didn't observe any statistically significant variables.

### Prevalence of dysphagia

The swallowing evaluation was done with semi-solid food and liquids in the 32 patients who underwent the FEES. The median score of the Murray scale was 1 (0.2-2) point. When we compared the Murray scale score between the group without laryngeal injuries [median 1 point (IQR 0-2)] and the group with laryngeal injuries [median 1 point (IQR 1-2)], we didn't observe any statistically significant differences between both groups ($p = 0.3$). In the assessment of semi-solid intake with the PAS scale we observed penetration through the AW in eight patients without aspiration in any of them. In the case of the liquids, nine patients (37.5%) showed aspiration and 5 showed penetration. Patients who couldn't be evaluated with liquids ($n = 9$) or semi-solids ($n = 8$) due to risk of aspiration were classified as "with dysphagia". The prevalence of dysphagia was 65.6% (21/32).

### Factors associated with dysphagia

The 32 evaluated subjects were classified in two groups: "with dysphagia" (PAS ≥ 2) [$n = 21$] and "without dysphagia" (PAS = 1) [$n = 11$]. When we related the presence or absence of dysphagia to the presence or absence of laryngeal injuries, we observed dysphagia in 8 out of 11 patients without laryngeal injury (72.7%) and in 13 out of 21 patients with laryngeal injury (61.9%). In the comparison of both groups, the differences weren't statistically significant ($p = 0.70$) (Table 4). When we compared the Murray scale score between the group without dysphagia [median 1 point (IQR 0-1)] and the group with dysphagia [median 1 point (IQR 1-2)], we didn't observe any statistically significant differences ($p = 0.09$).

### Other results

#### *Delirium*

The presence of *delirium* was evaluated after the patients had sustained 12 h of spontaneous ventila-

**TABLE 3.** Factors associated with the presence of laryngeal injuries

| Variables | All the patients (n = 32) | Without laryngeal injury (n = 11) | With laryngeal injury (n = 21) | p-value |
|---|---|---|---|---|
| Females, n (%) | 8 (25) | 2 (18.2) | 6 (28.6) | 0.68 |
| Age, median (IQR), years | 57 (49.5-65.5) | 60 (54-68) | 57 (47.5-65) | 0.75 |
| *Medical history, n (%)* | | | | |
| Hypertension | 7 (21.9) | 3 (27.3) | 4 (19) | 0.66 |
| Cardiac | 1 (3.1) | 1 (9.1) | 0 (0) | 0.34 |
| Respiratory | 2 (6.3) | 1 (9.1) | 0 (0) | 0.99 |
| Neurologic | 1 (3.1) | 1 (9.1) | 0 (0) | 0.34 |
| Diabetes | 5 (15.6) | 4 (36.4) | 1 (4.8) | 0.03 |
| Obesity | 6 (18.8) | 2 (18.2) | 4 (19) | 0.99 |
| Psychiatric | 1 (3.1) | 0 (0) | 1 (4.8) | 0.99 |
| APACHE II, median (IQR), score | 15.5 (10-24.2) | 15 (10-28) | 17 (10-24) | 0.64 |
| SOFA, median (IQR), score | 6.5 (4-9) | 7 (5-9.5) | 6 (4-9) | 0.49 |
| *Medication, n (%)* | | | | |
| NMBAs | 30 (93.8) | 10 (90.9) | 20 (95.2) | 0.99 |
| Antipsychotics | 30 (93.8) | 11 (100) | 19 (90.5) | 0.53 |
| Inotropic drugs | 27 (84.4) | 8 (72.2) | 19 (90.5) | 0.31 |
| RASS, median (IQR), score | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0.53 |
| Decubitus prone, n (%) | 17 (53.1) | 5 (45.5) | 12 (57.1) | 0.71 |
| ETT exchange required, n (%) | 7 (21.9) | 2 (18.2) | 5 (23.8) | 0.99 |
| Days with OTI, median (IQR) | 19 (17-21) | 19 (16-22) | 18.5 (17-20.7) | 0.98 |
| Days with TQT, median (IQR) | 25 (19-57) | 21 (17-57) | 31.5 (21-58.5) | 0.27 |
| Days with IMV, median (IQR) | 39.5 (31.7-46.7) | 39 (36-61.5) | 40 (25.5-47.5) | 0.75 |
| Days with AAW until FEES, median (IQR) | 43 (37-66.2) | 41 (36-56) | 49 (37-68.5) | 0.55 |
| Days with TQT until FEES, median (IQR) | 25 (18-36) | 21 (17-36) | 28.5 (18.5-43.5) | 0.45 |

tion and when they were decannulated, through the CAM-ICU. 34 patients received the initial evaluation; 11 (32.4%) obtained a positive result, 20 (58.8%) had a negative result, and 3 (8.8%) were non-evaluable. Upon discharge, 33 subjects had received this evaluation; 6 (18.2%) yielded a positive result, 26 (78.8%), a negative result, and 1 (3%) was non-evaluable.

### *Functional status*

We evaluated dependency in daily living activities (DLAs) at the beginning of the decannulation process and also upon discharge from the ICU through the Katz Index score. Thirty-two patients received the first evaluation. Two patients (6.3%) obtained an F category, and 30 patients (93.8%) obtained a G. Upon discharge, 30 patients received this evaluation; 1 (3.3%) of them obtained a C category, 2 (6.7%) had E, 8 (26.7%) had F and 19 (63.3%) had a G category.

### *Muscle strength*

We assessed the peripheral muscle strength on two occasions, at the beginning of the decannulation process and at the time of decannulation through the Medical Research Council (MRC) scale. At the initial evaluation ($n$ = 28), a median of 42 points was obtained (IQR 35-48.7), and in the second evaluation ($n$ = 26) there was a median of 48 points (IQR 40.7-56). A total of 26 patients received this evaluation in both instances. At the initial assessment, 17 patients (65.4%) showed values of <48 points. Upon discharge, 11 patients (42.3%) showed values of <48 points. The median

**TABLE 4.** Results related to the presence of dysphagia

| Variables | With dysphagia (n = 21) | Without dysphagia (n = 11) | p-value |
|---|---|---|---|
| Females, n (%) | 3 (14.3) | 5 (45.5) | 0.08 |
| Age, median (IQR), years | 60 (51.5-69) | 54 (46-60) | 0.18 |
| *Medical history, n (%)* | | | |
| Hypertension | 6 (28.6) | 1 (9.1) | 0.37 |
| Cardiac | 1 (4.8) | 0 (0) | 0.99 |
| Respiratory | 2 (9.5) | 0 (0) | 0.53 |
| Neurologic | 1 (4.8) | 0 (0) | 0.99 |
| Diabetes | 3 (14.3) | 2 (18.2) | 0.99 |
| Obesity | 3 (14.3) | 3 (27.3) | 0.39 |
| Psychiatric | 1 (4.8) | 0 (0) | 0.99 |
| APACHE II, median (IQR), score | 16 (12.5-28) | 15 (5-21.5) | 0.16 |
| SOFA, median (IQR), score | 6.5 (4-8.7) | 6.5 (3.2-10.5) | 0.82 |
| *Medication, n (%)* | | | |
| NMBAs | 19 (90.5) | 11 (100) | 0.53 |
| Antipsychotics | 21 (100) | 9 (81.8) | 0.11 |
| Inotropic drugs | 18 (85.7) | | 0.99 |
| RASS, median (IQR), score | 0 (0-0) | 0 (0-0) | 0.53 |
| Decubitus prone, n (%) | 10 (47.6) | 7 (63.6) | 0.47 |
| ETT exchangeT, n (%) | 4 (19) | 3 (27.3) | 0.66 |
| Days with OTI, median (IQR) | 18 (15.5-20) | 20 (18-27.5) | 0.07 |
| Days with TQT, median (IQR) | 25 (18.5-64.5) | 25.5 (18.7-37.2) | 0.49 |
| Days with IMV, median (IQR) | 41 (34.5-55) | 36.5 (22.2-43.2) | 0.19 |
| Days with AAW until FEES, median (IQR) | 41 (35.5-68.5) | 44 (41-64) | 0.58 |
| Days with TQT until FEES, median (IQR) | 25 (16.5-49) | 22.5 (18-32) | 0.51 |

References. IQR (interquartile range); APACHE II (Acute Physiology and Chronic Health Disease Classification System II); SOFA (Sequential Organ Failure Assessment score); NMBAs (neuromuscular blocking agents); RAAS (Richmond Agitation-Sedation Scale); ETT (endotracheal tube); OTI (orotracheal intubation); TQT (tracheostomy); IMV (invasive mechanical ventilation); AAW (artificial airway); FEES (Fiberoptic Endoscopic Evaluation of Swallowing)

**Figure 2.** Evolution of the Katz Index score about daily living activities in 30 patients evaluated on admission and upon discharge from the Decannulation Protocol Unit. C: independent in all functions except bathing and one more; E: independent in all functions except bathing, dressing, toileting, and one more; F: independent in all functions except bathing, dressing, toileting, transferring, and one more; G: dependent in all six functions.

of change according to the MRC was 3.5 points (IQR 0-8.5), with a minimum and maximum of 0 and 23 changepoints, respectively.

#### *Peak cough flow*

The cough strength was evaluated by registering the cough peak flow (CPF) in two instances: when the patient had a phonatory valve or cannula occlusion and, then, at the time of decannulation. Twenty one patients received the first evaluation with a median of 140 L/m (IQR 60-180) and 22 subjects received the second evaluation with a median of 165 L/m (IQR 105-205). Twenty patients were evaluated in both instances. The median of the CPF in the first and second instances was 140 L/m (IQR 65-180) and 165 L/m (IQR 95-215), respectively. The median of change in the CPF was 10 L/m (IQR 0-50), with a minimum and maximum change of –20 and 130 L/m, respectively.

#### *Blue staining test*

After 12 and 24 hours of spontaneous breathing we did the blue staining test for the purpose of starting with the decannulation process. The patient's tongue was stained with natural blue dye, then the tracheal tube cuff of the TQT cannula was deflated and either the cannula was occluded or a phonatory valve was placed. This test evaluates the presence of aspiration if there are stained secretions in the periosteum, through tracheal aspiration or through the subglottic catheter, and the presence of stained secretions is considered as a positive test. A positive result was observed in 5 out of 30 evaluated patients (16.7%).

#### *Decannulation*

All tracheostomized patients achieved decannulation before discharge and with a median of TQT time of 25 days (IQR 18.7-50.2), with a minimum and maximum of 8 and 123 days, respectively. When summing up the OTI days and the total TQT days, we obtained a median of AAW days of 48 d (36.7-75), with a minimum and maximum of 25 and 143 days, respectively.

#### *Dysphagia upon discharge*

At the time of discharge, 34 patients received the clinical swallowing evaluation; 7 patients with suspected dysphagia underwent a videofluoroscopic swallowing study. Six subjects (17.6%) had dysphagia at the time of hospital discharge.

#### *ICU and hospital stay*

The median of ICU length of stay was 50 days (IQR 37-68), with a minimum and maximum of 20 and 191 days, respectively. The median of hospital length of stay was 67 days (IQR 52.5-120.5), with a minimum and maximum of 16 and 287 days, respectively. Two patients died during their hospital stay.

## DISCUSSION

87.5% (*n*: 28/32) of tracheostomized COVID-19 patients showed at least one laryngeal injury evaluated through AW endoscopy. Most injuries were located in the glottic region. Similar results with a high frequency of laryngeal injuries were also reported in previous studies by Sandblom et al.,[11] Boggiano et al.[13] and Nauheim et al.[14] in similar cohorts of critically ill tracheostomized COVID-19 patients. Also, in these studies, the most commonly affected region was the glottic region. Due to the V-shaped anatomy of the larynx, it is particularly vulnerable to an injury, because of the mechanical effect exercised by the orotracheal tube.[8]

A previous study presented at the 2018 Congress of the Argentinean Society of Intensive Care Medicine of the same authors analyzed the presence of laryngeal injuries and dysphagia through the FEES. The study included 71 patients with a mean of 10 OTI days. 55 of those patients were tracheostomized. The frequency of laryngeal injuries in this study was lower (63%), laryngeal edema and abnormal movement of the vocal cords as the most prevalent.[15] These findings agree with Boggiano et al.,[13] who reported a lower percentage of laryngeal injuries in critically ill patients before the COVID-19 pandemic.

It has been reported that the frequency and severity of laryngeal injuries are directly related to the number of days with AAW, with important consequences that may result in respiratory failure and failure to extubate or decannulate.[6,8] However, we haven't found an association between the number of days with AAW and the development of laryngeal injuries. This coincides with other studies that didn't find such association either.[12,16]

The cause of the lack of statistical significance to show this association that has been thoroughly investigated could be our small sample size. The effects of the viral infection by SARS-CoV-2, which

haven't been completely clarified yet, could also explain this lack of statistical significance.

Despite the fact that we found high prevalence of laryngeal injuries, all the patients could be decannulated. We believe it's important to mention that 6 of the 32 patients who showed the most severe injuries took a longer time to achieve decannulation, with a mean of 50 days of TQT, due to the involvement of the AW permeability.

The greater use of the decubitus prone position as treatment of refractary hypoxemia has posed the hypothesis that the movement of the head and neck to reach such position would generate a bigger movement of the orotracheal tube, which would develop friction and excessive pressure over the AW structures that could generate a higher incidence of injuries.[12, 13] 54% of our patients were in decubitus prone position. However, we coudn't find an association between the decubitus prone position and the development of laryngeal injuries in our series of patients.

With regard to the characteristics of the sample, we found a higher percentage of males, mean age of 54 years, and a mean of OTI days of 19, which are similar to the reported characteristics.[17, 18] Arterial hypertension and obesity were the most prevalent comorbidities in our population of patients, just like the data reported in the Argentinean study of Estenssoro et al.[3] and the research carried out by Richardson et al.[18]

There are previous comorbidities that have been associated with a higher risk of laryngeal complications after extubation; the most important being: age, female gender, obesity, diabetes, arterial hypertension, and renal or liver failure.[8] These conditions influence tissue perfusion and the capacity of the tissues to scar, thus facilitating or worsening the AW injury. Also, some of these comorbidities are related to higher severity of the COVID-19 infection, thus suggesting that these patients have higher risk of intubation and also of suffering OTI sequelae.[14] We didn't find this relationship in our patient sample; and surprisingly, diabetes was more prevalent in the group without laryngeal injuries.

The prevalence of dysphagia in the series of patients under evaluation was 65.6% (21/32). Other studies conducted in COVID-19 patients obtained higher numbers. Sandblom et al.[11] and Boggiano et al.,[13] found that almost all analyzed patients had some degree of dysphagia assessed by the FEES.

Our lower percentage of dysphagia, compared to these studies, could be due to the kinetic treatment received by the patients from the moment they entered the decannulation protocol, prioritizing oral hygiene, stimulation of orofacial praxis, voluntary swallowing, sensorimotor laryngeal stimulation, stimulation of phonation, techniques to improve the respiratory muscle strength and expiratory flow, and the continuity of motor rehabilitation, according to each particular case.

The median score of the Murray scale in our study was 1 point (0.2-2). When we compared the score between the group without laryngeal injuries [median 1 point (IQR 0-2)] and the group with laryngeal injuries [median 1 point (IQR 1-2)], we didn't observe any statistically significant differences between both groups ($p = 0.3$). Previously mentioned studies reported higher numbers in this scale.[12]

The presence of dysphagia in critically ill tracheostomized patients is common. It has been stated that the presence of a TQT cannula increases the risk of aspiration. The physiopathological mechanism is multifactorial and includes causes related to oropharyngeal and laryngeal trauma, decreased oropharyngeal sensitivity due to the absence of airflow because of the tracheal tube cuff of the TQT cannula, the resulting loss of subglottic positive pressure, disuse atrophy, altered breathing-swallowing coordination, and alterations in the level of consciousness that impact on AW protection mechanisms and affect the safety of swallowing. We assume that apart from these mechanisms, now we have to add the effects of the SARS CoV-2 virus itself. A hypothesis has been posed that this virus can induce injuries in the central and peripheral nervous systems, because it affects the sensory and motor functions related to swallowing.[11] It isn't possible yet to draw a conclusion about the impact this virus has on said functions, but we shouldn't forget about the alteration in smell and taste, two symptoms observed with this infection, that could be an added value for the development of swallowing disorders.

However, the frequency of dysphagia found in our patients before the pandemic was 67.9%,[15] that is to say, very similar to the one reported in this study of the population with COVID-19. Future research is necessary to determine which is the real impact of the SARS-Co-V-2 virus on the

physiopathological mechanism of oropharyngeal dysphagia reported in these patients.

We didn't find any statistically significant association between laryngeal injuries and the presence of dysphagia that agrees with the results of our previous study.[15] And we didn't find any other publications investigating this association. The study of Rohuani et al. that was conducted in post-COVID-19 patients two months after ICU discharge showed an association between the laryngeal injuries evaluated through the FEES and the swallowing alterations through the EAT 10 (Eating Assessment Tool) questionnaire.[16]

In our study, 17.6% ($n$ = 6) of the patients showed dysphagia at the time of hospital discharge. On this regard, Boggiano et al. reported similar values of dysphagia upon discharge (20%).[13] Patients who presented dysphagia upon discharge received outpatient and telecommunication-based follow-up

All the patients achieved decannulation before discharge, and the median of TQT time was 25 days, with a CPF of 165 L/min (IQR 105-205), similar to data reported in the various studies, where a cough peak flow of 160 L/min or higher represents effective cough .[20]

A limitation to our study is the fact that we didn't calculate the rate of tracheostomized patients, because some data were missing from all the patients admitted to the intensive care unit that was necessary for us to assess the analyzed subgroup. On the other hand, we can mention our small sample size, even though it is similar to other studies available up to now about laryngeal injuries and dysphagia caused by COVID-19.

## CONCLUSION

This is the first study conducted in Argentina that reports the prevalence of laryngeal injuries and dysphagia in critically ill tracheostomized patients during the first wave of the COVID-19 pandemic; and a high prevalence was found. We believe that an early evaluation through the FEES has facilitated a timely diagnosis that allows us to guide the treatment individually and to define the moment for decannulation. It also provided us the necessary tools to define the feeding route until dysphagia resolution.

### Conflict of interest

Authors have no conflict of interest to declare.

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