

# Optimal Tracheostomy Timing Through Modeling Based on Severity of Vocal Cord Injury

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**BACKGROUND:** Endotracheal intubation is a routinely performed procedure in the ICU. Whereas it is recognized that endotracheal intubation can result in laryngeal and tracheal injury, this study evaluated factors that may affect the incidence of posterior vocal cord ulcers (PVCUs). **METHODS:** One thousand three hundred fifty-five patients were retrospectively screened from 2002–2018 that received a tracheostomy with routine bronchoscopy at a single institution. Post tracheostomy operative notes were reviewed and included only if proper visualization of the vocal cords was documented. Primary outcome measures included presence of PVCU, length of time on a ventilator until a tracheostomy, hospital length of stay, and mortality. Stratification of the data focused on the severity of the ulcer (mild, moderate, and severe) and was analyzed using analysis of variance, multivariate analysis, and Kaplan-Meier modeling of PVCU incidence over time. **RESULTS:** We enrolled 192 subjects with documentation of vocal cord visualization. Thirty-nine subjects did not have a PVCU, whereas 153 subjects did. A median duration of 9 (interquartile range [IQR] 5–13) d was associated with developing a mild PVCU, whereas individuals intubated for a median of 6 (IQR 4–7) d were ulcer free. Statistical difference between length of time on a ventilator before tracheostomy and the severity of the PVCU seen was significant ( $P < .001$ ). The Kaplan-Meier model showed that beyond 2 weeks of endotracheal intubation subjects will have > 80% chance of developing a moderate vocal cord ulcer. Whereas by day 7, there is only a 20% chance of developing a moderate ulcer. **CONCLUSIONS:** Earlier tracheostomy placement was associated with reduced severity of vocal cord ulcer formation. The Kaplan-Meier model suggests that waiting for 14 d is likely too long and earlier placement of a tracheostomy, within a week, may decrease the morbidity of posterior vocal cord injury. *Key words:* vocal cord ulcers; endotracheal tube; tracheostomy; ventilator dependent; COVID; ICU. [Respir Care 2023;68(2):255–259. © 2023 Daedalus Enterprises]

## Introduction

Endotracheal intubation is a routinely performed procedure in the ICU. When mechanical ventilation is a necessity, little attention is paid to the consequences of endotracheal intubation. Traditionally, patients can be intubated for 2 weeks before tracheostomy placement is performed.<sup>1,2</sup> The consequences of prolonged intubation can range from mild to severe ulcerations, granuloma formation, and laryngeal swelling.<sup>3</sup> In 2019, due to COVID-19, the higher rate of intubation, discontinuation of humidification for fear of contamination, and longer intubation times have led to an increase in various endotracheal injuries. Previous studies have shown tracheal injury ranging from mild edema to granuloma formation occurring within the first 3 days of intubation<sup>4</sup> and have attempted to define various parameters that can contribute to this injury such as endotracheal

tube (ETT) size, comorbidities prior to intubation, and body mass index (BMI).<sup>5</sup> However, many findings have been challenged and are inconsistent between different studies.

This current study aimed to compare the rate and severity of posterior vocal cord ulcers (PVCUs) and evaluate potential risk factors that contribute to posterior vocal cord ulceration at the time of tracheostomy placement visualized during routine bronchoscopy and predict the optimal timing through Kaplan-Meier event curve. Specifically, this study looked at the prevalence of PVCU development when age, sex, BMI, body surface area, and mortality are considered. Days of hospitalization and endotracheal intubation were also analyzed. We hypothesized that the prevalence and severity of ETT ulcers would correlate positively with prolonged invasive ventilation.

## Methods

The study was completed at Arrowhead Regional Medical Center, which operates as the county hospital within San Bernardino County, California. A retrospective chart review was conducted on 1,355 patients from 2002–2018 who were admitted and received percutaneous tracheostomy with routine bronchoscopy. Per protocol, all percutaneous tracheostomies are performed with bronchoscopy assistance.

After institutional review board approval, a query of the electronic health record for patients who received a tracheostomy with documentation or photograph of vocal cord visualization over the 16-y period (2002–2018) yielded 192 discrete in-patient stays. Various parameters were collected: age, sex, BMI, hospital length of stay, time to tracheostomy placement, and mortality. The study looked at whether subjects had developed a PVCU when a tracheostomy was performed and graded it as mild, moderate, and severe. Mild PVCUs were defined as minimal surrounding mucosal edema and no deformity to vocal cords. Moderate PVCU was defined as partial mucosal erosion around the ETT with partial closure of vocal cords, and severe PVCU had complete mucosal erosion and vocal cord defect that did not close during respiratory effort. During this collection interval, all ETTs were noted to be standard tubes with low pressure, large volume cuffs, and the associated ulcers were noted to be at the contact point of the tube laying against the posterior cords. The grading definition was defined at the initiation of our tracheostomy program for performance improvement. The final sample size ( $N = 192$ ) included 153 unique records of subjects that developed tracheal ulcer(s) and 39 that did not. Subjects without appropriate photograph or written documentation were excluded from the study. All percutaneous tracheostomies were performed by the surgical critical care team supervised by one of 3 board-certified surgical intensivists on medical, neurological, and surgical intensive care subjects. Subjects were intubated in the field by pre-hospital providers or in the emergency or operating room under the supervision of the anesthesia staff prior to being brought to the ICU utilizing laryngoscopy by direct or video visualization.

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## QUICK LOOK

### Current knowledge

Endotracheal intubations and tracheostomies are commonly performed procedures. Patients are often left intubated with an endotracheal tube (ETT) for 14 d before a tracheostomy is considered. Intubated patients can often end up with many complications, with the most debilitating resulting from posterior vocal cord ulcers (PVCUs) with vocal cord dysfunction. Additionally, various complications such as posterior subglottic stenosis, granuloma formation, and laryngeal edema can lead to persistent aspiration pneumonia.

### What this paper contributes to our knowledge

PVCU severity was correlated with longer ETT intubation. This study shows that earlier tracheostomy placement was associated with reduced severity of vocal cord ulcer formation. The Kaplan-Meier model suggests that waiting for 14 d is likely too long and earlier placement of a tracheostomy, within a week, may decrease vocal cord complications.

The samples were considered in 2 cohorts: subjects that developed an ulceration at the time of tracheostomy placement and subjects that did not. Descriptive statistics for the clinical characteristics between the 2 cohorts were assessed by 2-tailed *t* tests and chi-square tests where indicated. To determine variables associated with ulceration and potential confounders, a logistic regression model was conducted. Kaplan-Meier time to event was constructed to model the proportion of subjects free of PVCU, y axis, and in relationship to the duration of ETT intubation before tracheostomy, x axis. Data were compiled into an Excel spreadsheet, and statistical analysis was then performed using the IBM SPSS Statistics version 27.0 (IBM, Armonk, New York) software, unless otherwise indicated. A *P* value < .05 was considered statistically significant.

## Results

In the study sample ( $N = 192$ ), the median age of subjects that did not develop an ulcer was 44 (interquartile range [IQR] 27–59) y, and the median age of subjects that developed an ulcer was 56 (IQR 42–70) y ( $P < .001$ ). No difference was found between male and female incidence of ulcer development ( $P = .19$ ). The median length of hospitalization was 34 (IQR 19–48) d for subjects that did not develop an ulcer and 29 (IQR 20–48) d for subjects that did develop an ulcer ( $P = .11$ ). A median duration of 9 (IQR 5–13) d was associated with developing a mild PVCU, whereas individuals intubated for a median of 6 (IQR 4–7)

## OPTIMAL TRACHEOSTOMY TIMING BY VOCAL CORD INJURY

Table 1. Socio-demographic and Clinical Variables by Severity of Posterior Vocal Cord Ulcer

Characteristic	No PVCU (n = 39)	Mild PVCU (n = 52)	Moderate PVCU (n = 47)	Severe PVCU (n = 54)	Total PVCUs (n = 153)	P*
Age	44 (27–59)	51 (34–65)	51 (42–58)	65 (51–73)	56 (42–70)	< .001
Male, %	28 (72)	31 (60)	23 (49)	33 (61)	87 (57)	.19
BMI	27 (22–31)	26 (23–31)	25 (20–30)	27 (23–32)	26 (22–30)	.09
Hospital length of stay, d	34 (19–48)	28 (19–43)	38 (21–73)	28 (20–46)	29 (20–48)	.11
Time intubated until tracheostomy, d	6 (4–7)	9 (5–13)	10 (8–15)	11 (8–17)	10 (7–15)	< .001
Mortality, %	8 (13)	4 (8)	6 (13)	6 (11)	16 (10)	.83

Data are presented as n (%) or median (interquartile range).

\*Age, length of stay, duration on ventilator until tracheostomy, and body mass index analyzed with analysis of variance. All other comparisons with chi-square test.

PVCU = posterior vocal cord ulcer

BMI = body mass index

d were ulcer free. The length of intubation correlated with worsening degree of ulceration ( $P < .001$ ). The median BMI for subjects that were PVCU free was 27 (IQR 22–31) compared to 26 (IQR 22–30) for subjects that did develop a PVCU ( $P = .09$ ). For subjects without PVCU, the mortality rate was 13% compared to 10% for subjects that did develop a PVCU ( $P = .83$ ). The remainder of the results are summarized in Table 1.

Due to the potential for confounding clinical demographics, a logistic regression was performed. Consistent with the univariate analysis seen in Table 1, Table 2 shows a predictive logistic regression model that only finds days intubated on ventilator until tracheostomy placement to be statistically significant (odds ratio 1.353 [95% CI 1.181–1.549],  $P < .001$ ), and age was close to significance, (odds ratio 1.023 [95% CI 1.000–1.047],  $P = .051$ ).

We utilized a Kaplan-Meier analysis to model event over time (measured in days) elapsed from the start of ventilation until a tracheostomy was performed. The Kaplan-Meier curve, Figure 2, takes into consideration and calculates the number of days on a ventilator until placement of a tracheostomy and the proportion of subjects free from PVCU. By day 15, there was an 85% chance of developing a mild ulcer, 80% chance of developing a moderate ulcer, and 70% chance of developing a severe ulcer. At day 7,

there was a 40% chance of developing a mild ulcer, 20% chance of developing a moderate ulcer, and 10% chance of developing a severe ulcer.

### Discussion

ETT injuries commonly occur in a wide range of patients who are intubated for prolonged periods of time and can range from superficial mucosal ulceration to fibrosis or granuloma formation.<sup>6,7</sup> It is well described that patients who have longer durations of mechanical ventilation are more susceptible to endotracheal complications.<sup>8</sup> As explained by Hedden et al,<sup>9</sup> areas that are commonly affected are the posterior glottis, as the ETT tends to form a S shape with the posterior glottis acting as a fulcrum. Further articles mention that this level of injury on the mucosal surface can lead to strictures, fibrosis, and vocal impairment, which can affect the subject's quality of life, and is only recognized after the subject has survived the acute injury and has been successfully extubated or a tracheostomy has been placed.<sup>10</sup> It is not hard to imagine that once a severe ulcer develops the vocal cords are frozen open posteriorly and continue to allow aspiration of oral content even after the placement of a tracheostomy (Fig. 1).

A recent case report from Italy showed the first documented case of a PVCU in a patient with COVID-19 after approximately 9 d of intubation.<sup>11</sup> Additionally, another report showed 2 patients with COVID-19 who developed tracheal stenosis following prolonged intubation after undergoing tracheostomy.<sup>12</sup> Shinn et al<sup>10</sup> showed that a 7.0 mm or larger ETT, previous diagnosis of diabetes, and high BMI are the main predisposing factors for developing an ulcer and additionally, Stauffer et al<sup>13</sup> suggested a significant relationship between duration of endotracheal intubation and laryngeal injury. In this study, Shinn et al<sup>10</sup> showed that 57 versus 43 individuals developed acute laryngeal injury that were intubated for a median time of 3 d. Various studies have shown laryngeal injury is inevitable and minimization of ulcer development can produce the best quality of life. Campbell et al<sup>14</sup> reported cases of unilateral vocal fold

Table 2. Clinical Variables as Predictors of Ulcer Formation

Characteristic	OR (n = 231)	95% CI	P
Age	1.023	1.000–1.047	.051
Sex	0.541	0.214–1.366	.19
BMI	0.959	0.882–1.042	.32
Days of hospitalization	0.991	0.980–1.003	.14
Days intubated until tracheostomy	1.353	1.181–1.549	< .001

Binary logistic regression analysis of ulcer incidence.

Total subjects analyzed = 192. A Hosmer-Lemeshow test indicated that model fit was good (chi-square with 8 degrees of freedom = 6.052,  $P = .64$ ).

OR = odds ratio

BMI = body mass index

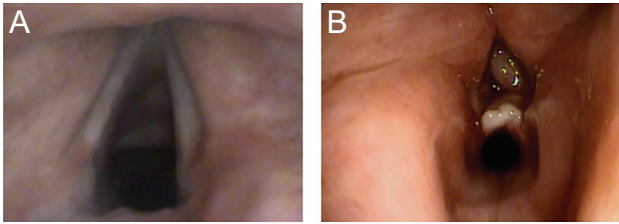


Fig. 1. A: A photograph of a moderate posterior vocal cord ulcer (PVCU) with partial closure of vocal cords during respiratory effort. B: A photograph of a severe PVCU with a bridge of fibrinous tissue around the previously placed endotracheal tube with inability to close the posterior aspect of the cord during respiratory effort.

immobility after prolonged endotracheal intubation. It is known that vocal cord dysfunction leads to increased risk of aspiration and laryngeal penetration.<sup>15</sup> Early tracheostomy can be one solution to the adverse effects of endotracheal intubation and prevent long-term morbidity and mortality from aspiration pneumonia.

PVCUs seen in intubated patients can lead to eventual posterior subglottic stenosis, which can be very debilitating and even life threatening, as a severe glottis injury can significantly impair glottis air flow leading to airway collapse.<sup>16</sup> Most studies and current practices agree that tracheostomy placement within 2 weeks in subjects who will need mechanical ventilation for prolonged periods of time is beneficial.<sup>2,17</sup> More recently, Colton House et al<sup>5</sup> found that intubated subjects will begin to show evidence of mucosal injury as early as 48 h regardless of endotracheal size  $\leq 8.0$ . By correlating risk factors to the severity of vocal cord injury, this study provides evidence that earlier timing, prior to 2 weeks, may decrease this injury and its related complications.

This study takes advantage of bronchoscopic visualization of the vocal cords during percutaneous tracheostomies and sought to determine what risk factors predisposed intubated subjects to develop PVCUs. Our study using analysis of variance found that the median day with no PVCU observed was on day (IQR 4–7) 6, whereas the incidences of mild PVCU were found by median day (5–13) 9. Using a Kaplan-Meier curve, we modeled the percentage of ulcer development over days with endotracheal intubation. We noted that there was a clear correlation of ulcer severity development during prolonged endotracheal intubation (Fig. 2). By day 7, the model predicted that there was a 20% chance of moderate vocal cord ulcer formation. Beyond day 14, the chance of moderate ulcer formation reached 80%.

When stratifying between no posterior ulcer versus different degrees of posterior cord ulcers (mild, moderate, and severe), there were significant differences in age and days intubated until the tracheostomy was placed. The longer the duration of intubation the more severe the PVCU. Santos et al and Colice et al both found duration of mechanical ventilation correlated to increase in ulcer development similar to

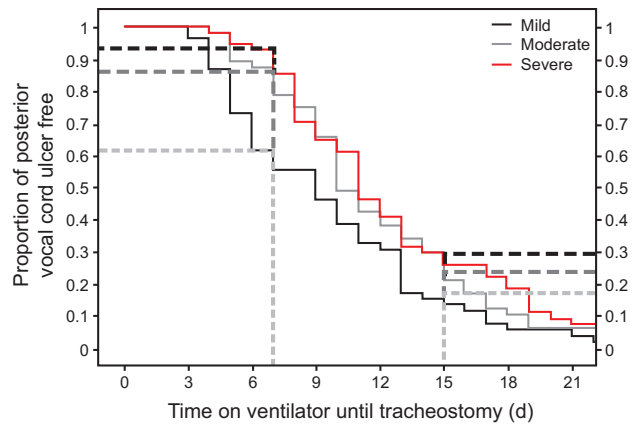


Fig. 2. Days on a ventilator until tracheostomy placement compared to severity of ulcer. The more time progressed until tracheostomy placement showed increased ulcer occurrence. On the right of the graph, we can see from the gridlines at day 15 there is an 85% chance of developing a mild ulcer, 80% chance of developing a moderate ulcer, and 70% chance of developing a severe ulcer. On the left of the graph, we can see from the gridlines at day 7 there is an 40% chance of developing a mild ulcer, 20% chance of developing a moderate ulcer, and 10% chance of developing a severe ulcer.

this study, whereas Colton House et al did not find any correlation.<sup>3,16,4</sup> The study from Colton House et al had a mean of 9.1 d of intubation, just at the threshold where this study indicated the risk of more severe ulcers would be significantly increased.<sup>4</sup> In addition to a limited number of 61 subjects, this may explain why his study did not find a difference.<sup>16</sup>

There are several limitations to this study. The retrospective nature of the data set may induce bias where positive findings are more likely to be documented, therefore favoring a higher incidence of PVCU. This, however, should not bias correlations to severity of PVCU and days on the ventilator. Observer bias may also be present when documenting the severity of PVCU. However, the severity of PVCU was defined prior to starting our percutaneous tracheostomy program for performance improvement at our institution, so the data are essentially prospectively collected with minimal observer variance. We also did not analyze other comorbidities and factors that may contribute to severity and risk of ulcer development such as diabetes and ETT size except for BMI. There are conflicting published data on tube size in relationship to injury.<sup>1,9,4</sup> Majority of our subjects was intubated with 7.5–8.0 size ETTs, and we felt that this size difference may not be meaningful. This may be an area of future study. Additionally, changes in methods of intubation during this long collection period, like the use of video- or bronchoscopy-assisted intubation, may introduce bias. However, our pre-hospital care and in-hospital intubation workflow has not changed during this period. Vocal cord injury during intubation may be masked by the development of the PVCU days after intubation or that the injury may be misinterpreted as a PVCU caused by



prolonged intubation. It is difficult to separate these potential injuries. We can use surrogates to potential injury like multiple attempts or difficulty during intubation but would still be limited in a retrospective study due to underreporting and late bronchoscopic visualization during tracheostomy placement. This is best studied in a prospective manner with early independent visualization of the cords.

Studies have shown that patients who are diabetic tend to have a higher incidence of laryngeal injury.<sup>10,18</sup> Shinn et al determined that type 2 diabetes mellitus and elevated BMI predisposed subjects to laryngeal ulcers and mucosal injury. Diabetes is known to inhibit pressure-ulcer healing due to a chronic inflammatory state along with microvascular disease.<sup>19</sup> In our study, we did not examine diabetes as a separate risk factor that could predispose our subjects to posterior cord ulcers. However, we did look at BMI as a potential risk factor. Previous studies supporting obesity as a risk factor for ulcer formation have suggested that critically ill, obese patients not only generate a stronger systemic inflammatory response but also have an increased tongue base size leading to greater posteriorly directed forces on the ETT. Interestingly, whereas Shinn et al suggested higher BMI was a significant risk factor for PVCUs, this study did not support this conclusion<sup>1</sup> (Table 1). Future prospective studies may further clarify these risk factors as well as randomizing ETT size to ulcer severity and development. Separating subjects by the underlying pathology that required prolonged intubation in future studies may further identify groups at risk of developing PVCUs as well as identifying potential effects of medications like steroids.

### Conclusions

This study shows that earlier tracheostomy was associated with reduced severity of vocal cord ulcer formation in mechanically ventilated subjects. Kaplan-Meier curve modeling showed a correlation of ulcer severity and prolonged endotracheal intubation. Beyond day 14, 80% of subjects would have a moderate ulcer, suggesting that earlier placement of a tracheostomy may decrease complications of vocal cord damage. Historically, waiting 14 days is likely too long, and earlier placement of a tracheostomy may decrease the morbidity of posterior vocal cord injury.

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### REFERENCES

1. Durbin CG. Indications for and timing of tracheostomy. *Respir Care* 2005;50(4):483-487.
2. Freeman BD, Borecki IB, Coopersmith CM, Buchman TG. Relationship between tracheostomy timing and duration of mechanical ventilation in critically ill subjects. *Crit Care Med* 2005;33(11):2513-2520.
3. Benjamin B. Prolonged intubation injuries of the larynx: endoscopic diagnosis, classification, and treatment. *Ann Otol Rhinol Laryngol* 2018;127(8):492-507.
4. Santos PM, Afrassabi A, Weymuller EA, Jr. Risk factors associated with prolonged intubation and laryngeal injury. *Otolaryngol Head Neck Surg* 1994;111(4):453-459.
5. Colton House J, Noordzij JP, Murgia B, Langmore S. Laryngeal injury from prolonged intubation: a prospective analysis of contributing factors. *Laryngoscope* 2011;121(3):596-600.
6. Benjamin B, Holinger LD. Laryngeal complications of endotracheal intubation. *Ann Otol Rhinol Laryngol* 2008;117(9\_suppl):2-20.
7. Bastian RW, Richardson BE. Postintubation phonatory insufficiency: an elusive diagnosis. *Otolaryngol Head Neck Surg* 2001;124(6):625-633.
8. Brodsky MB, González-Fernández M, Mendez-Tellez PA, Shanholtz C, Palmer JB, Needham DM. Factors associated with swallowing assessment after oral endotracheal intubation and mechanical ventilation for acute lung injury. *Ann Am Thorac Soc* 2014;11(10):1545-1552.
9. Hedden M, Ersoz CJ, Donnelly WH, Safar P. Laryngotracheal damage after prolonged use of orotracheal tubes in adults. *JAMA* 1969;207(4):703-708.
10. Shinn JR, Kimura KS, Campbell BR, Lowery AS, Wootten CT, Garrett CG, et al. Incidence and outcomes of acute laryngeal injury after prolonged mechanical ventilation. *Crit Care Med* 2019;47(12):1699-1706.
11. Bertone F, Robiolio E, Gervasio CF. Vocal cord ulcer following endotracheal intubation for mechanical ventilation in COVID-19 pneumonia: a case report from Northern Italy. *Am J Case Rep* 2020;21:e928126-1.
12. Gervasio CF, Averono G, Robiolio L, Bertolotti M, Colageo U, De Col L, Bertone F. Tracheal stenosis after tracheostomy for mechanical ventilation in COVID-19 pneumonia—a report of 2 cases from Northern Italy. *Am J Case Rep* 2020;21:e926731-1.
13. Stauffer JL, Olson DE, Petty TL. Complications and consequences of endotracheal intubation and tracheotomy: a prospective study of 150 critically ill adult subjects. *Am J Med* 1981;70(1):65-76.
14. Heitmilller RF, Tseng E, Jones B. Prevalence of aspiration and laryngeal penetration in subjects with unilateral vocal fold motion impairment. *Dysphagia* 2000;15(4):184-187.
15. Campbell BR, Shinn JR, Kimura KS, Lowery AS, Casey JD, Ely EW, Gelbard A. Unilateral vocal fold immobility after prolonged endotracheal intubation. *JAMA Otolaryngol Neck Surg* 2020;146(2):160-167.
16. Colice GL, Stukel TA, Dain B. Laryngeal complications of prolonged intubation. *Elsevier; Chest* 1989;96(4):877-884.
17. Fine KE, Wi MS, Kovalev V, Dong F, Wong DT. Comparing the tracheostomy dislodgement and complication rate of non-sutured neck tie to skin sutured neck tie fixation. *Am J Otolaryngol* 2021 Jan-Feb;42(1):102791.
18. Gaynor EB, Greenberg SB. Untoward sequelae of prolonged intubation. *Laryngoscope* 1985;95(12):1461-1467.
19. Assar ME, Angulo J, Rodríguez-Mañas L. Diabetes and ageing-induced vascular inflammation. *J Physiol* 2016 Apr 15;594(8):2125-2146.