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Laryngeal Injury From Prolonged Intubation: A Prospective Analysis of Contributing Factors

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Abstract

Objectives/Hypothesis—The factors leading to laryngeal injury due to intubation are not fully understood. This study sought to determine if duration of intubation, size of endotracheal tube, and/or type of endotracheal tube impact the degree of vocal fold immobility and other laryngeal injury upon extubation.

Study Design—Prospective study.

Methods—Sixty-one adult patients intubated for more than 48 hours were examined by recorded flexible nasolaryngoscopy shortly after extubation.

Results—Forty-one percent of patients had some degree of vocal fold immobility. However, neither the duration of intubation (range, 2–28 days; mean, 9.1 days), the size of endotracheal tube (range, 6 to 8), nor the type of endotracheal tube significantly affected the degree of laryngeal injury including vocal fold immobility. Additionally, none of the collected demographic information (age, gender, height, weight) significantly affected the degree of laryngeal injury.

Conclusions—In this cohort, duration of intubation, type of endotracheal tube, and size of endotracheal tube do not significantly correlate to the incidence of vocal fold mobility and degree of laryngeal injury noted after prolonged intubation.

Keywords

Laryngeal injury; prolonged intubation; vocal cord paralysis; hi-lo endotracheal tube; vocal cord immobility

INTRODUCTION

In clinical medicine today, patients in respiratory failure may be intubated for several weeks before conversion to tracheostomy is considered. This period of intubation may cause temporary or permanent laryngeal damage. The incidence of vocal fold immobility and other laryngeal pathologies (granulomas, laryngeal edema, and ulcerations) after prolonged intubation has been previously studied, but questions remain. Santos et al. evaluated the risk factors for laryngeal injury after intubation for more than 3 days in 97 patients in a prospective study.[1] They found that 97% of subjects had some form of laryngeal injury,

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ranging from mild edema to granuloma to vocal fold immobility, and that the associated risks were duration of intubation and presence of a nasogastric tube. They observed a 20% rate of vocal cord immobility that was associated with the duration of intubation and the size of the endotracheal tube (ETT).[1] Colice et al. also studied laryngeal injury after intubation for more than 4 days and noted a 94% incidence of laryngeal pathology, but the laryngeal findings correlated only to presence of neuromotor activity and performance of a tracheostomy, not to the duration of intubation or size of endotracheal tube.[2] Neither of these studies recorded the laryngoscopies for later review by a blinded observer.

Additionally, no study has examined the possibility of increased incidence of laryngeal injury with Hi-Lo Evac endotracheal tubes (Mallinckrodt, Athlone, Ireland). A number of studies have shown that Hi-Lo tubes may reduce ventilator-associated pneumonia due to continuous suctioning of subglottic secretions.[3–5] However, the outer diameter of the Hi-Lo ETT, for any given inner diameter, is approximately 1 mm greater than the equivalent outer diameter for the corresponding standard endotracheal tube. To date, there have not been any prospective studies in humans that evaluate whether these tubes result in any additional laryngeal injury, although Berra et al. in 2004 showed an increase in tracheal mucosal injury in sheep intubated with a Hi-Lo ETT when compared to a standard ETT.[6]

Because of the conflicting results of studies previously performed, we perceived a need to further examine factors that may contribute to laryngeal injury during prolonged intubation. Additionally, we were concerned that Hi-Lo Evac endotracheal tubes may result in more laryngeal injury than standard endotracheal tubes, given their larger outer diameter. To elucidate the incidence and risk factors for laryngeal injury, we performed recorded flexible nasolaryngoscopy on 61 patients no more than 24 hours after extubation. Our goal was to identify patients at greatest risk for laryngeal injury and specifically vocal fold immobility after prolonged intubation. This information could potentially change recommendations regarding the best time to consider conversion to tracheostomy, in addition to determining the size of endotracheal tube that is best suited for an individual patient. We hypothesize that the use of larger endotracheal tubes, increasing duration of intubation, and the presence of a Hi-Lo Evac endotracheal tube will result in a higher incidence of laryngeal pathology.

MATERIALS AND METHODS

Adult patients in the surgical and medical intensive care units at Boston Medical Center between April 2008 and August 2009, who were intubated for more than 48 hours, were eligible for this study. Once extubated, patients were approached for participation in this study as soon as they were alert and able to sign consent (no more than 24 hours after extubation). A flexible nasolaryngoscopy was performed on all patients after anesthetizing and decongesting the nose with 4% topical lidocaine mixed with neosynephrine. The participants were asked to repeat standardized vowels, consonants, and phrases to assess for vocal fold movement. They were also asked to sniff three times in succession to assess for maximal abduction of the vocal folds. The laryngoscopies were recorded to allow subsequent blinded review by a fellowship-trained laryngologist. This rater was blinded to all patient details, and the recordings were viewed without audio so that perceived hoarseness could not bias the rating. We initially intended to follow patients with either vocal fold immobility and/or granulomation tissue with a repeat examination 3 to 4 weeks after extubation. Very few patients were able to travel to our clinic for these appointments due to their poor health, so follow-up examinations were unavailable for most of the participants. Pregnant females, patients unable to consent for themselves, prisoners, patients <18 years of age, non–English-speaking patients, and patients with a known history of voice disorder, vocal fold immobility, thyroid surgery, cardiothoracic surgery, and/or neck trauma were excluded from this study.

The presence and degree of laryngeal pathologies were documented (see Table I for the rating sheet). Granulation tissue was defined as protruding, inflamed, fibrovascular tissue in the region the vocal process, whereas ulceration was defined as a loss of tissue in this same region (caused by the pressure of the endotracheal tube). Vocal fold immobility was rated at not present (i.e., normal mobility), mild (barely perceptible decreased motion), moderate (obvious decreased movement but not immobile), or severe (no vocal fold movement seen). Individual types of laryngeal injury (such as arytenoid edema, arytenoid erythema, vocal fold edema and erythema, granulation tissue, ulcerations, vocal fold immobility, and subglottic edema/narrowing) were correlated to the duration of intubation, size of the endotracheal tube, type of endotracheal tube, and the patient's age, height, weight, and gender. Additionally, an overall laryngeal injury score was assigned to each patient by assigning points to the individual types of laryngeal injury and adding these together (see point values at the top of Table I). This overall laryngeal injury score was also correlated to the duration of intubation, size of ETT, type of ETT, and patient demographic data.

All analyses were performed in SAS version 9.2 (Stata-Corp LP, College Station, TX). The following univariate procedures were employed: 1) for tests between categorical predictors and outcomes, simple χ^2 tests were used; and 2) for testing between numeric predictors and categorical outcomes, logistic regression analyses were used. Note that for outcomes with more than two levels, conditional logistic regression analyses using a cumulative logit model were employed. Additionally, due to the sample size and high number of levels for many of the variables examined, many models did not converge (or a simple χ^2 test was inappropriate); in these cases, Fisher χ^2 tests were employed. To test for significant differences within the sample (examination of single items, that is, not association testing), χ^2 tests of equal proportions were used.

RESULTS

A total of 61 patients were included in this study. Study demographics are shown in Table II. Ages ranged from 19 to 80 years old, with a mean of 56 years old. There was a slight male preponderance at 56%. Endotracheal tubes sizes ranged from 6 to 8. Thirty-nine percent of patients were intubated with a Hi-Lo ETT. Patients were intubated from 2 to 28 days, with a mean of 9.1 days. Every patient (N = 61) in this study had some degree of laryngeal injury, ranging from mild mucosal erythema and edema to severe vocal fold immobility, vocal process ulcerations, and granulation tissue.

Table III tabulates the types and incidence of laryngeal injury. Arytenoid edema, arytenoid erythema, and interarytenoid edema were by far the most common laryngeal injuries and were seen in 95% to 97% of patients. Vocal fold edema and erythema were the next most common laryngeal injuries at 66% and 89% of patients, respectively. Subglottic edema/narrowing occurred in 13% of patients (n = 8). Thirty-four percent (n = 21) of patients had vocal process ulceration, with 76% (n = 16) of those having bilateral ulceration. Unilateral left vocal fold ulceration was significantly more common (n = 4) than unilateral right-sided ulceration (n = 1) ($P = .02$). Vocal fold granulation tissue developed in 52% of patients (n = 32), with 78% of those being bilateral (Fig. 1). Statistically significantly more unilateral left-sided granulation tissue (n = 5) developed than unilateral right-sided granulation tissue (n = 4) ($P = .04$). Thirty-nine percent (n = 24) of all patients had some degree of vocal fold immobility, with 71% of those cases being mild; however, 29% of those cases had moderate or severe vocal fold immobility. Of the patients with vocal fold immobility, 46% had bilateral involvement of the true vocal folds; however, unilateral cord immobility was noted in 54%. There was a significantly higher percentage of isolated left-sided immobility (n = 12) compared to isolated right-sided immobility (n = 1) ($P < .0001$), and nearly one half of the isolated left-sided immobility was moderate to severe.

The patient demographics, such as age, height, weight, and gender, were correlated to the laryngeal injury score and specifically to the degree of vocal fold immobility using χ^2 tests. None of the patient factors had a statistically significant correlation with the overall laryngeal injury score, or with the individual types of laryngeal injury.

The duration of intubation and size of the endotracheal tube were also analyzed for a relationship with the overall laryngeal injury score, and specifically the degree of vocal fold immobility using standard *t* tests. Although no statistically significant relationships were found, several trends were noted. With increasing duration of intubation there was a nonsignificant trend of worse laryngeal injury score (P = .18), increasing severity of vocal fold immobility (P = .18), more granulation tissue development in the posterior glottis (P = .11), and greater presence of ulceration in the posterior glottis (P = .28). With larger endotracheal tubes there was a nonsignificant trend of worse vocal fold immobility (P = .21).

Finally, the presence of a Hi-Lo ETT was correlated to the overall laryngeal injury score and specifically to the degree of vocal fold immobility. Again, no statistical significance was achieved, but the presence of a Hi-Lo ETT showed a trend toward a worse laryngeal injury score (P = .15) and a worse severity of subglottic edema/narrowing (P = .25).

DISCUSSION

The presence of endotracheal tubes has been shown in numerous studies to cause various degrees of laryngeal injury.[1,2,7–10] Fortunately, most of these resolve within 1 month.[2] However, most authors support converting a patient in chronic respiratory failure to a tracheostomy after 7 to 9 days of intubation[11,12] prevent long-term damage to the larynx and trachea. Overall, our findings support the current practice of using endotracheal tubes as large as 10.7 to 10.9 mm in outer diameter (size 8.0 standard ETT) and for as long as an average of 9 days. In doing so, the risk of immediate laryngeal injury, although common, was not greater than those for patients intubated with smaller tubes or for shorter periods of time.

Our findings, that nearly every patient intubated for more than 48 hours has some degree of laryngeal injury, is consistent with prior similar studies. However, our study showed that 41% of patients had varying degrees of vocal fold immobility, which is greater than the 20% quoted in other research.[2] This difference could be explained by the ability of our recorded laryngoscopies to be paused and played back, thereby detecting subtleties that may have been missed during a single live viewing in previous studies. A possible etiology for vocal fold immobility resulting from intubation includes recurrent nerve injury from compression. Both Brandwein et al. and Cavo found the recurrent laryngeal nerve vulnerable to compressive injury between the inflated cuff of the endotracheal tube and the thyroid cartilage.[13,14] Additional possible etiologies for vocal fold immobility after prolonged intubation include myopathy/myositis of the intrinsic laryngeal muscles[15] or arytenoid dislocation.[16] We suggest that cricoarytenoid joint inflammation could also explain vocal fold immobility after intubation. Additional research would be required to further elucidate the mechanism of injury that is most commonly responsible for the vocal fold immobility seen after prolonged intubation.

This study indicates that patient demographics—including age, gender, height, and weight—are not significantly associated with worse laryngeal injury scores or the development of vocal fold immobility after prolonged intubation. Additionally, the size of the endotracheal tube did not statistically correlate to the degree of laryngeal injury, although with larger tubes there was a nonsignificant trend of increasing vocal fold immobility. In 1996, Brodsky et al. found that the average tracheal diameter is 22 mm for males and 17 mm for females.[17] They also noted that for females, height and weight were not reliable predictors of tracheal size.[17] The largest ETT used in this study was an 8.0, which has an outer diameter of approximately 10.7 to 10.9 mm. This relatively large-size endotracheal tube could still easily fit in a small female with a narrow trachea, and most certainly could fit in a larger male trachea. This may explain why there is no statistical correlation with gender, height, weight, or size of the endotracheal tube with the degree of laryngeal injury and vocal fold immobility.

The Hi-Lo ETT did not have statistically different laryngeal injury scores and degree of immobility when compared to the standard endotracheal tube, despite its slightly larger outer diameter with equivalent inner diameters. Again, this may be explained by the fact that even the slightly larger Hi-Lo tubes should have ample clearance from the tracheal walls in most adults, as discussed above. Despite the lack of statistical significance, the Hi-Lo tube did show a nonsignificant trend toward increased overall laryngeal injury, vocal fold immobility, and subglottic edema/narrowing. It is possible that these trends would become significant with a larger sample size.

In this study, increased duration of intubation was not associated with worse overall laryngeal injury or with vocal fold immobility. The mean duration of intubation in our study was 9 days and the range was 2 to 28 days. Although surprising, this result is consistent with the study done by Colice et al.[2] where their mean duration of intubation was 9.7 days (range, 4–28 days). Santos, however, did show a significant correlation between increasing duration of intubation and degree of laryngeal injury, and their mean duration was also 9 days.[1]

Many of the patients in this study developed moderate to severe laryngeal injury after a few days of intubation, whereas others were intubated for weeks with relatively minor laryngeal injury. Factors such as medical comorbidities (i.e., diabetes, malnutrition, congestive heart failure, liver failure, or other immunocompromised state), or presence of an nasogastric tube may play a larger role in a patient’s propensity to develop laryngeal injury from intubation than the duration of intubation. Gaynor and Greenberg showed a high incidence of laryngeal injury in insulin dependent diabetics who were intubated for 4 days, and recommended early tracheotomy for these patients.[8] Additionally, the degree of difficulty of intubation, the number of attempts required for successful intubation, and the person performing the intubation (resident, attending, paramedic) may all influence the amount of laryngeal injury seen upon extubation. Finally, the use of H2 blockers or proton pump inhibitors may also decrease the degree of laryngeal injury, as reflux is commonly seen in intubated patients.[19]

A final interesting finding in this study is that isolated left-sided injury (including immobility, ulceration, and granulation tissue) was statistically more frequent than isolated right-sided injury. To our knowledge, this has not been previously reported except with regard to granulomas. Several prior studies have shown a preponderance of left sided granulomas, but these were not caused by recent intubation.[20,21] Brandwein et al. and Cavo separately examined the course of the anterior branch of the recurrent laryngeal nerve and discovered it to be vulnerable to compression between the inflated cuff of the endotracheal tube, the lateral projection of the abducted arytenoid, and the thyroid cartilage, although no mention was made about the laterality of the injury in either study.[13,14] Additional studies are required to further elucidate the mechanism of injury resulting in vocal fold immobility and the reasons that left-sided injury may be more common than right-sided injury.

Some of the laryngeal changes observed in this study may have been present prior to intubation. We could not obtain preintubation laryngoscopies on our subjects because one rarely, if ever, knows when a patient is going to develop a medical illness requiring prolonged intubation before it happens.

CONCLUSION

In this group of 61 subjects, patient demographics, size of the endotracheal tube, duration of intubation, and presence of a Hi-Lo compared to a standard endotracheal tube did not significantly correlate to the degree of laryngeal injury or vocal fold immobility. In patients intubated between 2 and 28 days (mean 9.1 days) with endotracheal tubes as wide as 10.7 to 10.9 mm, there is no difference in the risk of immediate laryngeal injury. Although laryngeal injury is common after prolonged intubation, larger endotracheal tubes (up to size 8.0) were no more likely to cause injury than smaller tubes. Longer periods of intubation (average, 9 days; maximum, 28 days), did not further risk laryngeal injury in this group of patients. Finally, Hi-Lo tubes were not shown to have a greater risk of laryngeal injury compared to similar inner-diameter standard endotracheal tubes.

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Fig. 1.
Laryngoscopic image showing left vocal fold immobility and bilateral posterior glottic granulation tissue. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

TABLE I

Fiberoptic Laryngoscopy Evaluation Sheet.

Points	0	1	2	3
Arytenoid edema	None	Mild	Moderate	Severe
Arytenoid erythema	None	Mild	Moderate	Severe
Interarytenoid edema	None	Mild	Moderate	Severe
Vocal fold edema	None	Mild	Moderate	Severe
Vocal fold erythema	None	Mild	Moderate	Severe
Right vocal process ulceration	None	Mild	Moderate	Severe
Left vocal process ulceration	None	Mild	Moderate	Severe
Right vocal process granulation tissue	None	Small	Medium	Large
Left vocal process granulation tissue	None	Small	Medium	Large
Right vocal fold immobility	None	Mild	Moderate	Severe/Fixed
Left vocal fold immobility	None	Mild	Moderate	Severe/Fixed
Subglottic edema/narrowing	None	Mild	Moderate	Severe

TABLE II

Study Demographics (N = 61).

	% (No.)
Age, yr	
<18	0 (0)
18–35	13 (8)
36–55	28 (17)
56–70	44 (27)
>71	15 (9)
Gender	
Male	56 (34)
Female	44 (27)
Race	
Caucasian	44.3 (27)
African American	31.1 (19)
Hispanic	8.2 (5)
Not reported	16.4 (10)
Size of endotracheal tube	
6	3.3 (2)
7	18 (11)
7.5	41 (25)
8	36 (22)
Multiple	1.7 (1)
Duration of intubation, d	
2–7	50.8 (31)
8–14	29.5 (18)
15–21	13.1 (8)
22–28	6.6 (4)
Hi-Lo	
Yes	57.3 (35)
No	39.3 (24)
Not documented	3.3 (2)

TABLE III

Incidence of Laryngeal Pathologies (N = 61).

	Total, % (No.)	Mild, % (No.)	Moderate, % (No.)	Severe, % (No.)
Arytenoid edema	95 (58)	49 (30)	36 (22)	10 (6)
Arytenoid erythema	96.7 (59)	34.4 (21)	62.3 (38)	0
Vocal fold edema	65.6 (40)	54.1 (33)	11.5 (7)	0
Vocal fold erythema	88.5 (54)	62.3 (38)	23 (14)	3.3 (2)
Interarytenoid edema	95 (58)	39.3 (24)	50.8 (31)	4.9 (3)
Subglottic edema/narrowing	13.1 (8)	8.2 (5)	4.9 (3)	0
Vocal process ulceration, any	34 (21)			
Bilateral	26.2 (16)	16.4 (10)	9.8 (6)	0
Right only	1.6 (1)	1.6 (1)	0	0
Left only	6.5 (4)	4.9 (3)	1.6 (1)	0
Vocal process granulation tissue, any	52.5 (32)			
Bilateral	37.7 (23)	29.5 (18)	8.2 (5)	0
Right only	6.5 (4)	6.5 (4)	0	0
Left only	8.2 (5)	8.2 (5)	0	0
Vocal fold immobility, any	39 (24)			
Bilateral	18 (11)	16.4 (10)	0	1.6 (1)
Right only	1.6 (1)	1.6 (1)	0	0
Left only	19.7 (12)	9.8 (6)	3.3 (2)	6.5 (4)