The Laryngoscope

Optimal Timing of Surgical Intervention Following Adult Laryngeal Trauma

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Objective: Laryngeal trauma is an infrequent diagnosis with a scarcity of published data. We aim to further define the factors associated with positive surgical outcomes of adult laryngeal trauma.

Study Design: Multi-institution database analysis.

Methods: Of the 1.9 million trauma cases from the National Trauma Database (NTDB), 564 adult trauma events were selected with ICD-9 codes specific to laryngeal trauma.

Results: Laryngeal trauma was seen predominately in white (61.5%), middle-aged (40.6 years), male (83.7%) patients experiencing blunt (70.7%) laryngeal injury with multiorgan system (92.2%) trauma. There was an overall 17.9% mortality rate. Within the 564 cases, 133 direct laryngoscopies, 185 tracheostomies, 53 laryngeal suturing, and 60 laryngeal fracture repairs were performed. In univariate negative binomial regression models, trauma severity ($P \leq .01$), placement of tracheostomy (P lt; .01), and delayed tracheostomy placement ($P = .04$, .03, .048) were associated with increased ventilator dependence, intensive care unit (ICU) stay, and overall hospital admission duration. Multivariate regression models demonstrated significant associations between tracheostomy performed within 24 hours and shortened ICU stay ($P = .03$, $\beta = -.28$, SE = 1.7) and overall hospital stay ($P = .009$, $\beta = -.23$, SE = 3.1).

Conclusions: The NTDB allows study of the largest laryngeal trauma cohort in modern literature. Although complexities arise in the treatment of laryngeal traumas, when indicated, surgical airway should be placed within 24 hours of presentation to improve the overall hospital course.

Key Words: Adult laryngeal trauma, surgical intervention.

Level of Evidence: 2c.

***Laryngoscope*, 121:2122–2127, 2011**

INTRODUCTION

Laryngeal trauma patients present with significant acute complications that demand strict attention by experienced providers. With an overall mortality approximated at 2%,[1] airway management is paramount. However, even with a secured airway, laryngeal lacerations and fractures frequently require further therapeutic interventions.

Although the general principles of laryngeal trauma management have been typically well accepted, questions persist with regard to the timing of surgical intervention. As many authors have described immediate surgical intervention,[2–4] others have also proposed a 3- to 5-day waiting period prior to operative intervention.[5,6] Clinical experience of the authors has provided the basis for these recommendations; however, demonstrative data identifying optimal timing of surgical intervention for the adult laryngeal trauma patient is lacking. It is therefore the goal of the current study to identify laryngeal trauma outcomes that are affected by timing of surgical interventions.

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Editor's Note: This Manuscript was accepted for publication May 13, 2011.

This study was presented at the Triological Society Annual meeting, Chicago, Illinois, April 29–30, 2011.

The authors have no financial disclosures for this article.

The authors have no conflidcts of interest to disclose.

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DOI: 10.1002/lary.22163

MATERIALS AND METHODS

This study was exempt from institutional review board approval.

The current study was carried out utilizing the National Trauma Data Bank (NTDB), Version 7.2, issued May 2010, Chicago, IL.[7] The NTDB is an incident-based trauma repository maintained by the American College of Surgeons Committee on Trauma. The NTDB records trauma encounters from over 900 trauma centers from across the United States and includes approximately 2.7 million unique cases, encompassing the admission period between 2001 and 2005. It must be noted that the NTDB remains the full and exclusive copyrighted property of the American College of Surgeons. The American College of Surgeons is not responsible for any claims arising from works based on the original data, text, tables, or figures within the present manuscript.

The research datasets are downloaded in DBF format and subsequently combined into SAS v9.1.3 (Cary, NC) for data management. The cases were then limited to incidents including laryngeal trauma diagnoses by filtering the cases utilizing International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes (807.5, 807.6, 874.00, 874.01, 874.10, 874.11). The dataset was further limited to age greater than 17 years. Surgical interventions are coded through specific procedural descriptors. The descriptors were reviewed and were grouped within six independent laryngeal surgical interventions (diagnostic laryngoscopy = 31.4; tracheostomy = 31.1, 31.29, 31.74; laryngeal suture = 31.6, 31.61, 31.69, 31.71, 31.73, 31.75, 31.79; laryngeal fracture repair = 31.64).

A number of data points are included within the NTDB that describe the injury severity of each trauma incident. The registry directly codes for the mechanism of trauma: penetrating or blunt. For each trauma incident, related diagnoses are recorded. The incidents that code for laryngeal diagnoses only were recoded as isolated injury; all others were recorded as multisystem injury. Glascow Coma Scale (GCS) is a well-utilized neurologic scale assessing the level of consciousness. The GCS is composed of three components (eyes, verbal, and motor) and is graded on a 3-to 15-point scale, where 3 represents comatose state and 15 represents normal neurologic function. The GCS included in the present study represents the grading given on initial presentation in the Emergency Department. The NTDB also codes for two well-accepted trauma indices. The first is the Injury Severity Score (ISS), which is a validated measure predictive of morbidity and mortality based on anatomic injury.[8] The ISS scores injury to six anatomic sites, and the highest three sites' score is squared. The sum of the squared scores is the ISS and can range from 0 (no injury) to 75 (unsurvivable injury). The Trauma Score–Injury Severity Score (TRISS) is also included within the NTDB. TRISS is a complex equation that predicts probability of survival based on the ISS, patient age, mechanism of injury, GCS, and presenting vital signs. TRISS is resulted as a percent probability of survival. It has been validated as a reliable comprehensive and objective trauma-scoring index.[9]

Descriptive and analytic statistics were applied comparing surgical groups to the overall cohort. Surgical groups were not exclusive, and as such, individual incident lines could be assigned to more than one surgical code. The cohort did not uphold normal distributions across dependent and independent variables. As such, demographic and clinical presenting differences were analyzed via Kruskal-Wallis (KW) and Mann-Whitney U (MW) tests for continuous variable independent group comparisons, and via chi-squared and fisher exact tests for categorical variables as appropriate. The main dependent measures (ventilator dependence, ICU stay, hospital admission) were composed of count measures. Tests of normality demonstrated overdispersion for each dependent variable. Therefore, Negative Binomial Regression models were applied for each independent variable individually. Negative Binomial Regression is the test of choice when a count variable is encountered due to the inherent rightward skew of the data.[10] Statistical significance was defined as $P < .05$. Significant univariate variables were included within multivariate regression models. Data was analyzed with SPSS v17.0 (Chicago, IL).

RESULTS

A total of 564 laryngeal trauma events were identified between 2001 and 2005. Table I displays the demographic and clinical information for the total cohort stratified by surgical treatment. Males were substantially more likely to present with laryngeal trauma. Patients undergoing tracheostomy had a statistically worse clinical condition as graded by the Glasgow Coma Scale (GCS) and the Trauma Injury Severity Score (TRISS), but not by the Injury Severity Score (ISS). Patients undergoing laryngoscopy demonstrated improved clinical condition as seen by improved ISS and TRISS.

Hospital-related outcomes were chosen as statistical dependent variables: length of mechanical ventilation, length of intensive care unit (ICU) stay, and length of overall hospital admission. The independent variable of interest was length of time from presentation to operative intervention. Secondary independent variables include demographic and presenting clinical information listed in Table I.

Table II demonstrates univariate negative binomial regression models for each outcome measure. The beta factor can be also labeled as the regression coefficient, and is a measure of the degree of linear association between the outcome measure and the listed independent variable. A number of variables reached significance in its association with each outcome measure. As expected, positive prognostic items such as GCS and TRISS demonstrate a negative beta factor. In other words, patients presenting with higher level of consciousness or higher probability of survival demonstrate univariate significance toward better hospital outcomes. Alternatively, time to tracheostomy performance demonstrates a positive beta factor, signifying that for each unit delay in tracheostomy performance (days) will result in an increase in the outcome measure, and will be a product of the days delayed multiplied by the beta factor.

Patients undergoing tracheostomy for laryngeal trauma demonstrated about 1 day more of mechanical ventilation, ICU stay, and hospital admission compared to those traumas not requiring tracheostomy. Patients requiring direct laryngoscopy, laryngeal suturing, or fracture repair were associated only with longer hospital admissions, but only fracture repair was associated with changes in ICU stays ($P = .04$).

Time interval to tracheostomy demonstrated positive univariate significance toward all three hospital-related outcomes, signifying delay in performance of tracheostomy could increase the length of ventilation, ICU stay, and hospital admission. To maintain clinical relevance the time cutoff of 24 hours was then utilized in further multivariate analysis.

Figure 1A–C displays standard box plots stratifying hospital-related outcomes by time to tracheostomy placement. Subsequently, multivariate regression analysis was performed including the significant univariate factors from Table II, with individual exception. First, due to significant and substantial correlation ($\rho = -.67$) ISS and TRISS were not included together in a single model. As such, TRISS was chosen for inclusion in that this score includes the ISS. Second, race variable was not included in the model as the limited representative samples limited the power of analysis. The multivariate modeling factors of surgical intervention timing are included in Figure 1. Although the associative relationship between tracheostomy timing and ventilator dependence does not maintain significance, delay in tracheostomy placement is significantly associated with increased ICU stays and overall hospital admissions.

DISCUSSION

As demonstrated presently and elsewhere,[1] laryngeal trauma is most frequently encountered with

TABLE I.
Laryngeal Trauma Demographic and Presenting Clinical Data.

	Laryngeal Trauma Patients (n = 564)	Laryngoscopy (n = 133)	Tracheostomy (n = 185)	Laryngeal Suture (n = 53)	Laryngeal Fracture Repair (n =60)
Mean age (SD)	40.6 (17.2)	38.4 (15.3)	40.3 (17.0)	36.9 (17.9)	39.4 (18.9)
				$P = .033$*	
Gender					
Female	92 (16.3%)	13 (9.8%)	31 (16.6%)	7 (13.2%)	4 (6.7%)
Male	471 (83.7%)	119 (90.2%)	156 (83.4%)	46 (86.8%)	56 (93.3%)
		$P = .02$ (chi)			$P = .040$‡
Race (not inclusive)					
Black	115 (22.6%)	22 (19.0%)	45 (26.0%)	13 (26.0%)	9 (17.0%)
Hispanic	57 (11.2%)	16 (13.8%)	19 (11.0%)	9 (18.0%)	5 (9.4%)
White	313 (61.5%)	72 (62.1%)	101 (58.4%)	25 (50.0%)	36 (67.9%)
Preexisting condition (not inclusive)					
Asthma	6 (5.8%)	3 (12.0%)	2 (3.7%)	2 (15.4%)	2 (15.4%)
Chronic alcohol use	11 (10.6%)	2 (8.0%)	3 (5.6%)	0 (0%)	0 (0%)
History of cancer	34 (32.7%)	6 (24.0%)	24 (44.4%)	5 (38.5%)	4 (30.8%)
Hypertension	13 (12.5%)	4 (16.0%)	5 (9.3%)	4 (30.8%)	2 (15.4%)
SBP in ED (SD)	125.9 (46.3)	141.5 (30.6)	132.7 (36.5)	142.0 (31.7)	138.4 (35.8)
		$P < .001$*		$P = .027$*	
Respiration in ED	15.1 (9.5)	16.6 (8.7)	15.1 (9.7)	13.8 (10.8)	16.0 (8.3)
GCS (SD)	10.1 (5.5)	10.8 (5.3)	9.0 (5.5)	8.8 (5.4)	9.8 (5.7)
			$P = .001$*	$P = .045$*	
Mechanism					
Blunt	396 (70.7%)	93 (70.4%)	113 (61.1%)	22 (41.5%)	46 (78.0%)
Penetrating	164 (29.3%)	39 (29.5%)	72 (38.9%)	31 (58.5%)	13 (29.3%)
			$P < .001$†	$P < .001$†	
Isolated Laryngeal Injury	44 (7.8%)	12 (9.0%)	9 (4.8%)	3 (7.8%)	6 (10.0%)
Mean ISS (SD)	23.4 (15.6)	19.3 (11.3)	23.6 (13.1)	21.5 (12.6)	23.7 (13.3)
		$P = .004$*			
Mean TRISS (SD)	0.718 (0.362)	0.816 (0.283)	0.697 (0.336)	0.702 (0.315)	0.741 (0.320)
		$P = .002$*	$P = .047$*		
Laryngeal injury type					
Closed fracture	380 (67.4%)	85 (63.9%)	106 (57.3%)	17(32.1%)	42 (70.0%)
Open fracture	80 (14.2%)	24 (18.0%)	33 (17.8%)	7 (13.2%)	15 (25.0%)
Uncomplicated wound	85 (15.1%)	19 (14.3%)	35 (18.9%)	22 (41.5%)	2 (3.3%)
Complicated wound	19 (3.4%)	5 (3.8%)	11 (5.9%)	7 (13.2%)	1 (1.7%)
			$P = .003$†	$P < .001$†	$P = .006$†

*Kruskal–Wallis (KW).
†Chi Square.
‡Fisher Exact.
Mean values and variable counts are subdivided by surgical intervention group. Surgical interventions are not exclusive and single patients may be included in >1 subgroup. Significant *P*-values are displayed only.
SD = standard deviation; SBP = systolic blood pressure; ED = emergency department; GCS = Glascow Coma Scale; ISS = Injury Severity Score; TRISS = Trauma Score–Injury Severity Score.

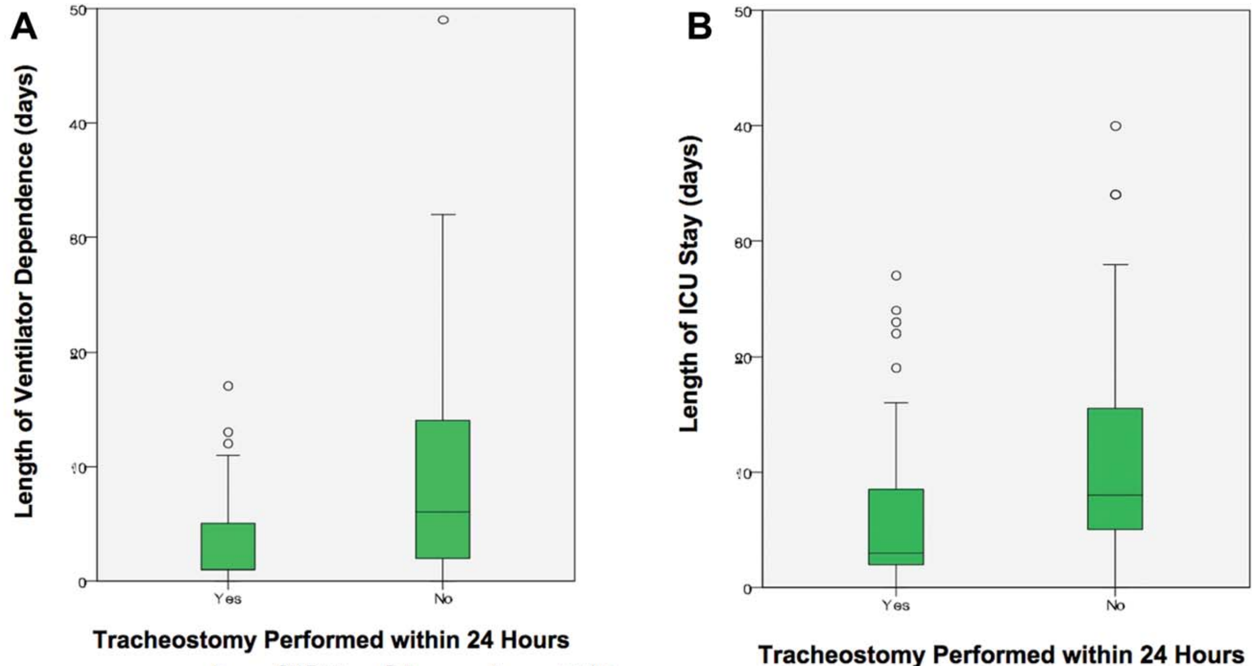
multiorgan injury. As such, the optimal management focused on the larynx is typically complicated by concurrent treatments. However, superseding all other treatments, obtaining a secured airway is the primary fundamental management objective for every laryngeal trauma patient.[4]

Following acute airway management, laryngeal injuries are managed based on the severity of injury and specific elements of each lesion. A classification and treatment protocol has been described by Schaefer:[11] Group I laryngeal traumas demonstrate only minor laryngeal edema or lacerations. Typically, this group can be treated with steroids, antibiotics, antireflux therapy, and close observation. Group II includes more demonstrative edema or hematomas without exposed cartilage. Diagnostic endoscopy and tracheostomy are frequently indicated for this group. Group III laryngeal traumas demonstrate massive edema or large mucosal lacerations

TABLE II.
Univariate Regression Models for Hospital-Related Outcomes.

	Ventilator Dependence (Days)					ICU Stay (Days)					Hospital Admission (Days)				
	Beta	Std. Error	Lower 95% CI	Upper 95% CI	*P*-Value	Beta	Std. Error	Lower 95% CI	Upper 95% CI	*P*-Value	Beta	Std. Error	Lower 95% CI	Upper 95% CI	*P*-Value
Age	0.00	0.00	0.00	0.01	.29	0.00	0.00	0.00	0.01	.38	**0.01**	**0.00**	**0.00**	**0.01**	**.01**
Male gender	−0.04	0.18	−0.38	0.31	.84	−0.08	0.14	−0.35	0.19	.57	0.05	0.12	−0.19	0.29	.68
Race (Black)	**0.33**	**0.16**	**0.02**	**0.64**	**.04**	0.09	0.13	−0.16	0.35	.48	0.04	0.12	−0.19	0.27	.73
Systolic blood pressure	0.00	0.00	0.00	0.00	.23	**0.00**	**0.00**	**0.00**	**0.01**	**.02**	**0.01**	**0.00**	**0.00**	**0.01**	**.00**
Resperation rate	0.00	0.01	−0.02	0.01	.56	0.01	0.01	−0.01	0.02	.35	0.01	0.01	−0.01	0.02	.34
GCS	**−0.08**	**0.01**	**−0.11**	**−0.06**	**.00**	**−0.06**	**0.01**	**−0.08**	**−0.04**	**.00**	**−0.04**	**0.01**	**−0.06**	**−0.02**	**.00**
Blunt force trauma	−0.02	0.15	−0.31	0.27	.88	−0.04	0.12	−0.26	0.19	.75	−0.05	0.10	−0.25	0.15	.62
ISS	**0.03**	**0.01**	**0.02**	**0.04**	**.00**	**0.03**	**0.00**	**0.02**	**0.04**	**.00**	**0.01**	**0.00**	**0.01**	**0.02**	**.00**
TRISS	**−0.72**	**0.20**	**−1.11**	**−0.32**	**.00**	**−0.47**	**0.17**	**−0.81**	**−0.13**	**.01**	−0.21	0.15	−0.51	0.09	.16
Laryngoscopy patients	0.21	0.14	−0.07	0.48	.14	−0.06	0.12	−0.29	0.17	.61	**0.44**	**0.11**	**0.23**	**0.65**	**.00**
Days to laryngoscopy	0.01	0.03	−0.04	0.06	.81	0.03	0.03	−0.02	0.08	.18	0.04	0.02	0.00	0.08	.07
Tracheostomy patients	**1.20**	**0.13**	**0.94**	**1.46**	**.00**	**0.94**	**0.11**	**0.73**	**1.14**	**.00**	**1.06**	**0.10**	**0.88**	**1.25**	**.00**
Days to tracheostomy	**0.03**	**0.02**	**0.00**	**0.07**	**.04**	**0.03**	**0.02**	**0.00**	**0.07**	**.03**	**0.03**	**0.02**	**0.00**	**0.06**	**.048**
Laryngeal suture patients	−0.26	0.24	−0.73	0.21	.28	0.30	0.17	−0.03	0.63	.07	**0.55**	**0.15**	**0.26**	**0.85**	**.00**
Days to suturing	0.03	0.06	−0.09	0.15	.62	0.05	0.03	−0.01	0.11	.10	0.03	0.03	−0.03	0.09	.29
Fracture repair patients	0.30	0.18	−0.06	0.66	.11	**0.31**	**0.15**	**0.01**	**0.61**	**.04**	**0.52**	**0.14**	**0.24**	**0.80**	**.00**
Days to fracture repair	0.01	0.04	−0.06	0.08	.79	0.04	0.03	−0.01	0.09	.11	0.03	0.02	−0.02	0.07	.23

The dependent count variable of is analyzed with individual Negative Binomial Regression models. Significant associations are marked in bold.
GCS = Glascow Coma Scale; ISS = Injury Severity Score; TRISS = Trauma Score–Injury Severity Score; Std = standard; CI = confidence interval.



	b	Std Error	Beta	t	p value
Ventilator Dependence	-3.965	2.190	-.202	-1.810	.074

	b	Std Error	Beta	t	p value
ICU Stay	-5.163	1.713	-.283	-3.014	.003

	b	Std Error	Beta	t	p value
Hospital Admission	-8.198	3.094	-.229	-2.650	.009

Fig. 1. Tracheostomy within 24 hours affects hospital-related outcomes. Box plots demonstrate substantial improvements in ventilation dependence (A), ICU stays (B), and hospital admissions (C). Additionally, multivariate regression models display significant association between timing of tracheostomy with ICU stays and length of hospital admission [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.].

with exposed cartilage. Additionally, findings of displaced cartilaginous fractures or vocal fold immobility are included in Group III. Group IV traumas include destabilization of the laryngeal structure either through the disruption of the anterior commissure or through unstable displaced fracture lines. Groups III and IV require fracture reduction and rigid fixation in addition to mucosal coverage of exposed cartilage edges. Tracheostomy is uniformly indicated.

Despite relative congruency amongst practitioners with regard to the diagnosis and treatment of laryngeal injuries, the timing of these established treatment strategies has been the subject of debate. Initially, the clinical consensus was to allow time for swelling to subside, and after 5 days, laryngeal injuries would be addressed surgically.[5,6] However, these reports were based largely on conceptual foundations of wound healing and personal experience. With time, laryngeal trauma data began supporting prompt intervention, and management strategies based on initial reports has become antiquated. Leopold reported on his 20 year experience with 200 laryngeal traumas, and based on a 24-hour threshold, his data support prompt surgical intervention.[2] With an impressive collection of 112 laryngeal trauma patients over a 32-year period, Butler et al.[4] stratified their patients based on surgery within or over 48 hours. Despite the delayed surgical group containing a larger proportion of suboptimal voice and airway outcomes, a considerable heterogeneity of surgical interventions existed in this study. Additionally, this study included a relatively small subgroup of delayed intervention ($n = 18$). Cherian et al.[3] also reported improved clinical outcomes with prompt surgical management; again, their results were substantially limited by statistical power with an overall 30 incidents within the analysis. However, similar to reports that support a delayed surgical approach, there are reports encouraging prompt surgical management of these patients without describing data.[12]

To this end we analyzed the substantive trauma databank of the NTDB to analyze the largest single group of adult laryngeal trauma. Our findings support previous reports demonstrating improved outcomes with expedient surgical intervention. The statistical analyses herein support urgent tracheostomy in the laryngeal trauma patient. Controlling for external factors such as severity of multiorgan system trauma and demographic factors, tracheostomy placement within 24 hours expedites length of ICU stays and time to hospital discharges. Although the principles we present herein reflect similar treatment strategies as Leopold[2] and Bultler et al.,[4] this is the first study specifically identifying hospital-related outcomes in the laryngeal trauma patient.

Although prompt tracheostomy is encouraged, Jewett et al.[1] echoes a critical consideration demonstrated in the present study: tracheostomy placement drastically worsens hospital-related outcomes. When compared to the patients not requiring surgical airway, tracheostomy patients were subjected to drastic increases to ICU stays and overall hospital admission. The surgical teams must therefore be certain that tracheostomy is indicated on a patient-to-patient basis. Once the indication for tracheotomy has been established, the present study demonstrates the value of expeditious surgical intervention.

A criticism of the current study is the lack of clinical outcome measures. Although the NTDB includes a communication function code, Functional Independence Measure (FIM), this measure was designed to test for central nervous functioning and its application toward laryngeal dysfunction is unsubstantiated. The FIM was therefore not included within the outcome measures. Additionally, although such measures that include severity of injury indices (i.e., ISS, TRISS, GCS) were included in the multivariate analysis, we cannot absolutely ascertain the causative factors, which may have lead to a delay in the performance of tracheostomy. However, the inclusion of these trauma severity indices does control for external confounding factors.

The NTDB contains other limiting factors. First, the database as it stands is a convenience sample and therefore inherits the registry deficiencies of participating hospitals. The NTDB is comprised of a disproportionate number of large hospitals with typically more severe trauma cases. Therefore, within the present study, no population-based incident inferences were drawn. Additional drawbacks to the convenience-reporting of the NTDB include the presence of selection and information biases. Due to these shortcomings as well as the limitation of statistical association in proving causation, further investigation is required to better elucidate the optimal surgical management of the adult laryngeal trauma patient.

CONCLUSION

Based on multivariate analysis we support placement of indicated tracheostomies within 24 hours of adult laryngeal trauma presentation. Although laryngeal trauma patients requiring tracheostomies demonstrate prolonged hospital-related outcomes, tracheostomies performed within 24 hours are associated with significantly reduced ICU stays and overall hospital admission. Our data substantiates the recent literature, which recommends expedient placement of tracheostomy. Similar findings were not identified for other surgical interventions including direct laryngoscopy, laryngeal suturing, or laryngeal fracture repair. Additional investigation should concentrate on functional outcomes following early surgical interventions.

Acknowledgment

The authors acknowledge the significant data management and statistical guidance from the consultants of the UCLA Academic Technology Services.

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