The Laryngoscope

External Laryngotracheal Trauma: Incidence, Airway Control, and Outcomes in a Large Canadian Center

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Objectives/Hypothesis: Laryngotracheal trauma encompasses a subset of relatively uncommon yet life-threatening injuries requiring prompt intervention to prevent short- and long-term aerodigestive tract sequelae. Minimal literature exists regarding laryngotracheal injuries on a population level, particularly among Canadian centers.

Study Design: Case series.

Methods: Regional health databases containing in-patient admissions, emergency department visits, and trauma service activations using International Classification of Diseases (ICD) diagnostic codes were queried to identify all laryngotracheal injuries diagnosed from April 1, 1995, to December 31, 2011. Health records and diagnostic imaging were evaluated for mechanism, injuries, airway management, and long-term aerodigestive function.

Results: Eighty-nine patients met inclusion criteria, equating to 1/1042 admissions and 1/2478 emergency presentations. Nineteen percent of injuries were severe (Schaefer-Fuhrman score ≥ 4). Airway intervention was performed at presentation in 65% of patients, with 13.5% necessitating emergent surgical airway; 52% underwent investigative or interventional airway surgery. Nine patients (16%) had long-term moderate or severe dysphonia; 14.5% had dysphagia. Odds ratio for death and long-term dysphonia among severe compared to minor laryngotracheal injuries were 7.1 (95% CI = 1.4–35.4) and 17.2 (95% CI = 3.3–91.1), respectively. Several factors were identified that predicted airway management and outcomes.

Conclusion: Traumatic laryngotracheal injuries are more common than previously reported, due to increased recognition. Many can be managed nonoperatively; however, cases require individual evaluation with judicious airway management and intervention to minimize aerodigestive sequelae. Severe injuries are associated with death and dysphonia but not with dysphagia.

Key Words: Voice, dysphonia, swallowing, dysphagia, laryngology.

Level of Evidence: 4.

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INTRODUCTION

Laryngotracheal trauma is a potentially devastating injury that requires a high index of suspicion and prompt intervention to maximize survival and aerodigestive outcomes. Traumatic laryngotracheal injuries can be classified as external or internal, and due to blunt or penetrating mechanisms. Among external laryngotracheal injuries, a severity scheme from 1 to 4 that was defined by Schaefer[1] describes mucosal and structural injuries; later it was modified by Fuhrman to include complete laryngotracheal separation and has become the most common grading system.[2] Afforded protection by surrounding bony structures and numerous soft tissue suspensions, injuries to the laryngotracheal apparatus are considered infrequent, constituting 1/14,583 to 1/42,528 emergency room visits.[3,4] Questions exist regarding the current true incidence of these injuries and the long-term aerodigestive outcomes.

Respiration, phonation, and airway protection are all at risk following laryngeal injuries that potentially compromise the structural or neurologic integrity of the apparatus. Butler et al. found a preponderance of poor vocal, airway, and swallowing outcomes among patients with severe laryngotracheal injuries, suggesting that early intervention (less than 48 hours after presentation) is associated with better vocal and airway outcomes.[5,6] For patients with milder injuries (grade 1 or 2), nonoperative management appeared appropriate and did not adversely affect outcomes. Various algorithms have been proposed for the management of laryngotracheal injuries[7–16]; however, significant variation can occur within each severity class and management must be individualized.

The purpose of our study was to determine the incidence, airway interventions, long-term aerodigestive sequelae among patients suffering external laryngotracheal trauma, and factors predictive of these outcomes. Utilizing a data storage system capturing all patient encounters in the province of Alberta, we took a population-based approach to better evaluate these parameters. Results from

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this study may improve the management of these devastating injuries with the intention of maximizing both short-term and long-term aerodigestive outcomes.

MATERIALS AND METHODS

Patient Identification

A retrospective cohort study containing all adults ($\geq$ 16 years) with external traumatic laryngotracheal injuries between April 1, 1995, and December 31, 2011, was completed using the Southern Alberta Trauma Database (SATD) and the Alberta Health Services (AHS) Data Information, Management, and Recording division (DIMR). The SATD contains prospectively collected data on all severely injured (Injury Severity Score [ISS] $\geq$ 12) trauma patients admitted to the Foothills Medical Center (FMC), an adult level I tertiary-care trauma hospital responsible for southern Alberta, southwestern Saskatchewan, and southeastern British Columbia. DIMR prospectively records all emergency department visits and in-patient admissions at health care facilities operated by the AHS. Each database was independently queried for patients, with laryngotracheal injuries documented as primary and secondary diagnoses—or high likelihood of laryngotracheal injury due to neck trauma—using ICD-9 and ICD-10 codes involving the neck and laryngeal structures (Table I). Both the DIMR and SATD databases are prospectively collected, with preselected information recorded after patient discharge or death.

Database analysis produced potential subjects' names, age, unique identifying numbers, primary and secondary diagnoses, presentation date and time, interventions, and discharge date and disposition. Following cohort identification, all subjects were cross-referenced between databases to eliminate duplicates and to populate a list of subjects with potential laryngotracheal injuries. The patient cohort was refined following the inclusion of confirmed laryngotracheal injury through diagnostic imaging, clinical examination, or operative identification of injury. Patients were excluded if under age 16; initial presentation, diagnosis, and primary management were performed outside hospitals within the city of Calgary; absence of documented laryngotracheal injury; laryngotracheal injury resulting from endolaryngeal trauma such as intubation or caustic ingestion; laryngotracheal injury secondary to resuscitation; or no visit corresponding to a patient's unique identifying numbers associated with the presentation date.

TABLE I.
ICD-9 and ICD-10 Diagnostic Codes Used in Cohort Identification.

International Classification of Disease Code	Diagnosis
ICD-9	
8075	Fracture larynx/trachea, closed
8076	Fracture larynx/trachea, open
8740	Open wound larynx/trachea, no complications
8741	Open wound larynx/trachea, with complication
9252	Crushing injury of neck
ICD-10	
s1280	Fracture of other parts of neck: includes hyoid bone/larynx/thyroid cartilage/trachea-open/closed
s110	Open wound involving larynx and trachea-complicated/uncomplicated
s170	Crushing injury of larynx and trachea

Population values were determined from Statistics Canada at major and minor censuses undertaken every 5 years.[16–18] Best-fit regression was performed for intercensus years to estimate population between census data points.

Injury Classification

Laryngotracheal injuries were defined to include all injuries involving bony, cartilaginous, or soft tissue structures extending from the superior boundary of the supraglottis (tip of the epiglottis, plus the hyoid bone) to the inferior boundary of the subglottis (inferior border of the cricoid cartilage), plus the first and second tracheal rings. All other injuries were recorded according to the organ affected. Injuries were graded based on clinical and radiographic data according to the Schaefer-Fuhrman scale.[2]

Data Extraction and Analysis

Electronic and paper records (Emergency Medical Services records, emergency department notes, trauma team flowsheets, ICU transfer summaries, discharge summaries, death summaries, medical examiner records, specialist consult records, diagnostic imaging and reports, physician and nursing notes, and operative notes) associated with the encounter were reviewed.

Follow-up data was obtained from health records in attending otolaryngology surgeons' offices, electronic medical records, and voice clinic data. The Calgary Health Region has one tertiary laryngologist (JDB) who oversees all voice clinic encounters. Voice quality was classified as normal, mild, moderate, or severe dysphonia. Airway was reported as impaired based on the presence of dyspnea with correlative anatomic abnormalities noted. Dysphagia was declared present if the patient consistently experienced abnormalities with any foods on history, modified barium swallow (MBS), or flexible endoscopic evaluation of swallowing (FEES).

Between groups testing for means were conducted with students t tests. The χ^2 testing assessed intervention association with injury severity. Associations between presenting symptoms, laryngeal injuries, and comorbid injuries with airway intervention, airway surgery (excluding purely diagnostic laryngoscopy, bronchoscopy, or esophagoscopy), and adverse outcome were conducted with bivariate analyses utilizing Fisher's exact test or χ^2. Features identified as potentially predictive for these events were then assessed for correlations and for clinical importance to determine factors appropriate for multivariate regression. Selected factors were combined into a multivariate regression analysis model to identify independent predictors. Following the classification of injuries as nonsevere or severe (Schaefer-Fuhrman grade ≤ 3 or ≥ 4, respectively), odds ratios were calculated for adverse outcomes based on injury severity group. Statistical analysis was performed using Stata 12 (StataCorp LP, College Station, TX). P values less than 0.05 were considered statistically significant. This study received ethical approval from The University of Calgary Conjoint Health Research Ethics Board.

RESULTS

Epidemiology and Demographics

Eighty-nine patients with documented laryngotracheal injuries were included for final data analysis (Fig. 1), providing a laryngotracheal injury incidence of 1/2422 emergency department visits and 1/1019 hospital admissions. Upon exclusion of purely upper tracheal (first and second ring) injuries, the population was

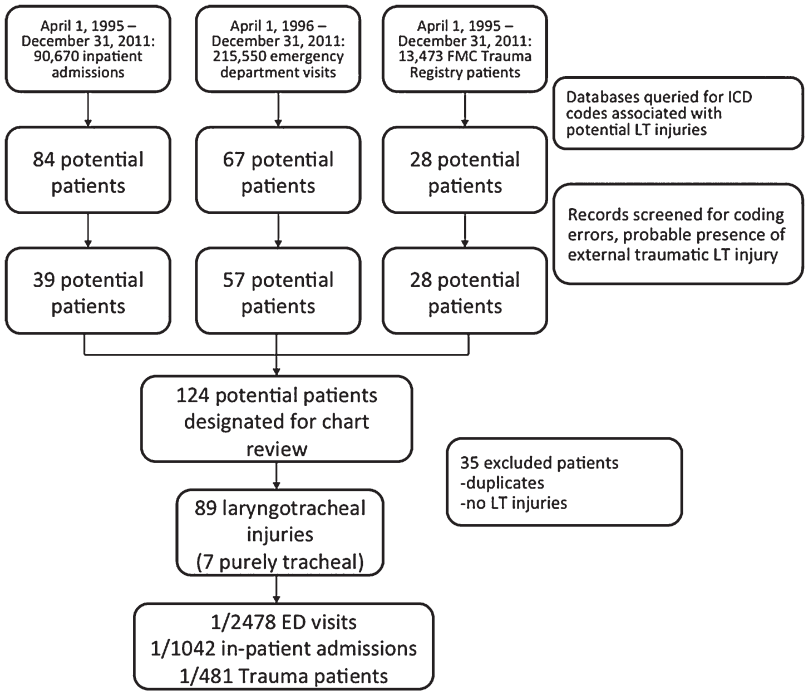

Fig. 1. Consort diagram describing cohort identification. ED = emergency department; FMC = Foothills Medical Centere LT = laryngotracheal.

reduced to 82 laryngeal injuries, with injury incidences of 1/2629 emergency department visits and 1/1106 in-patient admissions specifically for traumatic external laryngeal injuries. In terms of a population-based incidence, laryngotracheal injuries occurred at a mean rate of 5.5 per million people per year, with a trend for increased incidence (Fig. 2).

Mean patient age was 37.3 years (median = 33 years, range = 18–80 years), the majority male (Table II). Injury severity classified according to the Schaefer-Furhman scale found 80.9% of injuries were grade 3 or less (mean = 2.51, median = 2). In those patients admitted to the trauma surgery service (n = 45), mean Schafer-Fuhrman score was 2.60, while those admitted to otolaryngology (n = 20) had a mean Schafer-Fuhrman score of 2.45 ($P = 0.57$).

Presentation, Mechanism, Specific and Associated Injuries

Figure 2 demonstrates injury incidence per year, subdivided by blunt or penetrating mechanism. Features

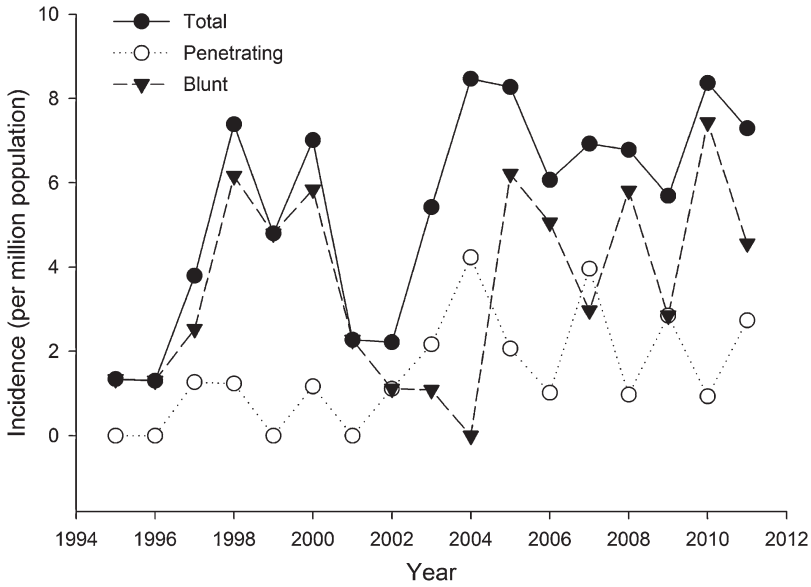

Fig. 2. Annual incidence of laryngotracheal injuries classified according to mechanism.

TABLE II.
Patient Demographics and Injury Features.

	Value	Percentage (%)
Total	89	
Mean age (median)	37.3 years (33.0 years)	
Male	73	82.0
Female	16	18.0
Injury severity		
S-F 1	13	14.6
S-F 2	40	45.0
S-F 3	19	21.3
S-F 4	12	13.5
S-F 5	5	5.6

S-F = Schaefer-Fuhrman injury grade.

reported with the injuries seen in our cohort are presented in Tables (III–VI). It remains a disturbing finding that 14.2% of patients had no presenting symptoms or signs suggesting underlying laryngotracheal injury, and no correlation with injury grade existed. In this series, blunt trauma accounted for 69.7% of all injuries. However, when assault-related injuries are considered separately, the penetrating mechanism frequency increased to 54.2%. The most frequently injured structure in the laryngotracheal apparatus is the thyroid cartilage, while soft tissue injuries most frequently affected the supraglottic region. Greater than 60% of patients had associated injuries, often involving multiple organs.

Airway and Aerodigestive Tract Management

Airway intervention was employed in 65.2% of patients with laryngotracheal trauma (Fig. 3). The χ^2 analysis demonstrated a clear association between airway intervention and increasing injury grade ($P = 0.001$). Slightly more than half of all cases were initially intubated (51.7%), although several patients were intubated for emergent operative intervention of an associated injury and not specifically the laryngotracheal injury. Emergent surgical airways were obtained in 12 patients (13.5%). Specific operative interventions and the frequency used with respect to severity of injury are listed in Figure 4; notably, 47.2% of laryngotracheal injuries were managed nonoperatively. In cases suspicious for esophageal injury, barium esophagram and surgical exploration were the primary modalities for diagnosis; esophagoscopy was uncommonly performed.

Factors predictive of either airway intervention or interventional airway surgery by bivariate analyses are demonstrated in Tables (III–VI). Following reduction by correlation testing and assessing clinical utility, multivariate regression and odds ratios for these factors are shown in Tables VII and VIII. The only factor statistically correlated with conservative management instead of airway intervention was odynophagia, presence of which dictated 9.1-fold decreased odds of needing either intubation or surgical airway compared to patients without odynophagia. Conversely, both stridor at presentation and motor vehicle collision (MVC) mechanism were statistically associated with airway intervention, independent of associated injuries. Stridulous patients were 9.1-fold more likely to require airway intervention than

TABLE III.
Presenting Symptoms and Signs of Laryngotracheal Trauma Patients.

Symptom/Sign	Number (percent*) of patients	Association with Airway Intervention (*P value*)	Association with Surgical Intervention (*P value*)	Association with Adverse Outcome (*P value*)
None	13 (14.6)	0.130	0.442	0.512
Symptoms				
Aphonic	1 (1.1)	1.00	0.483	0.397
Hoarseness/dysphonia	35 (3.9)	0.02	**0.090**	0.954
Odynophagia	23 (2.6)	**<0.001**	**0.001**	**0.004**
Dysphagia	13 (14.6)	0.009	0.071	0.176
Pain	10 (11.2)	0.003	0.091	0.073
Dyspnea	11 (12.4)	0.317	0.659	0.467
Snoring	1 (1.1)	0.348	1.00	N/A
Signs				
Hemoptysis	6 (6.7)	0.416	0.447	1.00
Stridor	15 (16.9)	**0.075**	0.321	0.130
Tracheal deviation	1 (1.1)	1.00	1.00	1.00
Subcutaneous emphysema	19 (21.3)	0.184	0.048	0.467
Pneumomediastinum	4 (4.5)	1.00	0.274	1.00
Respiratory distress/airway obstruction	24 (27.0)	**<0.001**	**<0.001**	0.103

*Percentages do not add up to 100 due to multiple injuries.
P values of factors selected for multivariate regression following correlational analysis and clinical evaluation are in bold text.

TABLE IV.
Mechanisms of Laryngotracheal Trauma Patients.

Mechanism	Number (percent*) of Patients	Association with Airway Intervention (*P value*)	Association with Surgical Intervention (*P value*)	Association with Adverse Outcome (*P value*)
Blunt	64 (71.9)	0.001	<0.001	0.977
Penetrating	25 (28.1)	**0.001**	**<0.001**	0.977
Assault	24 (27.0)	0.857	0.776	0.783
Sports and recreation	23 (25.8)	**0.011**	0.046	0.284
Hockey	9 (10.1)	0.060	0.159	0.226
Motor vehicle collision	17 (19.1)	**0.045**	0.335	0.019
MVC: automobile	10 (11.2)	0.155	0.513	0.204
MVC: motorcycle	5 (5.6)	0.654	0.193	0.058
MVC: bicycle	1 (1.1)	1.00	1.00	1.00
MVC: pedestrian	1 (1.1)	1.00	1.00	0.397
Self-inflicted	7 (7.9)	0.414	**0.005**	1.00
Occupational	6 (6.7)	1.00	1.00	1.00
Other	11 (12.4)	0.430	0.524	0.298

P values of factors selected for multivariate regression following correlational analysis and clinical evaluation are in bold text.
*Percentages do not add up to 100 due to multiple injuries.
MVC = motor vehicle collision.

nonstridulous patients. All patients presenting with respiratory distress or tracheal injuries required airway intervention and represented perfect predictors for airway intervention.

When factors predictive of surgical intervention were assessed by multivariate regression, respiratory distress (13.8-fold increased odds of requiring surgery compared to nondistressed patients), penetrating injuries (9.6-fold increased odds compared to blunt mechanism), and self-inflicted injuries support surgical management. In our study, all self-inflicted injuries were aggressive, penetrating injuries requiring surgical intervention. Hyoid bone fractures statistically were significantly associated with nonsurgical management. Similar to the airway intervention analysis, patients presenting with odynophagia trend toward nonoperative management, but this was not statistically significant.

TABLE V.
Laryngeal Injuries of Laryngotracheal Trauma Patients.

Injury	Number (percent*) of Patients	Association with Airway Intervention (*P* value)	Association with Surgical Intervention (*P* value)	Association with Adverse Outcome (*P value*)
Laryngotracheal Injuries				
Structural framework injuries	52 (58.4)	0.064	0.058	0.181
Hyoid bone fracture	11 (12.3)	0.143	0.005	1.00
Thyroid cartilage fracture	27 (30.3)	0.845	0.173	0.124
Cricoid cartilage fracture	17 (19.1)	0.964	0.041	0.142
Tracheal cartilage fracture or intercartilagenous laceration	20 (22.5)	<0.001	**0.002**	0.024
Soft tissue injuries	50 (56.2)	0.946	0.177	0.493
Cricoarytenoid joint subluxation	2 (22.5)	1.00	1.00	1.00
Cricothyroid membrane	11 (12.4)	0.317	0.003	1.00
Supraglottic	28 (31.5)	0.282	0.039	0.350
Vocal fold/glottic	17 (19.1)	0.242	0.780	1.00
Subglottic	15 (16.9)	0.542	0.286	0.836
Vocal fold hypomobility/immobility	6 (6.7)	0.177	1.00	0.389
Hypopharyngeal injury	4 (4.5)	0.608	1.00	0.557

P values of factors selected for multivariate regression following correlational analysis and clinical evaluation are in bold text.

TABLE VI.
Laryngeal Injuries of Laryngotracheal Trauma Patients.

Associated Injuries	Number (percent) of Patients	Association with Airway Intervention (*P* value)	Association With Surgical Intervention (*P* value)	Association With Adverse Outcome (*P* value)
None	35 (39.3)	<0.001	0.033	0.014
Facial fractures	18 (20.2)	0.881	0.154	0.267
Orbital injuries	1 (1.1)	1.00	0.331	1.00
Spinal injuries	9 (9.9)			
Cervical spine fractures	8 (9.0)	0.708	0.715	**0.032**
Lower vertebral fractures	2 (2.2)	1.00	1.00	0.514
Intracranial injuries	11 (12.4)	0.216	0.111	**0.013**
Subdural hematoma	3 (3.4)	0.549	0.608	0.154
Subarachnoid hemorrhage	4 (4.5)	0.293	0.350	0.058
Intracranial hemorrhage	2 (2.2)	1.00	1.00	0.397
Intraventricular hemorrhage	1 (1.1)	1.00	0.483	0.397
Traumatic brain injury	10 (11.2)	0.155	0.188	0.103
Great vessel injury	2 (2.2)	0.541	1.00	1.00
ICA dissection	1 (1.1)	1.00	1.00	1.00
Great vessel transection	1 (1.1)	1.00	1.00	0.397
Cerebrovascular accident	1 (1.1)	1.00	1.00	0.397
Anoxic brain injury	1 (1.1)	1.00	0.483	N/A
Skull base fracture	5 (5.6)	0.654	0.670	0.377
Pharyngeal laceration	1 (1.1)	1.00	1.00	1.00
Intrathoracic injuries	18 (20.2)	0.004	0.023	**0.008**
Pneumothorax	11 (12.4)	0.089	0.111	0.421
Pulmonary contusion	6 (6.7)	0.088	0.424	0.377
Hemothorax	2 (2.2)	0.541	1.00	0.154
Esophageal rupture/laceration	6 (6.7)	0.088	0.103	0.058
Intraabdominal	2 (2.2)	0.541	1.00	0.514
Liver laceration	2 (2.2)	0.541	1.00	0.514
Splenic laceration	1 (1.1)	1.00	1.00	1.00
Other musculoskeletal or soft tissue	28 (31.5)	0.235	0.809	0.556

P values of factors selected for multivariate regression following correlational analysis and clinical evaluation are in bold text.
Percentages do not add up to 100 due to multiple injuries.
ICA = internal carotid artery.

Outcomes Analysis

Outcome results are shown in Tables IX and X. Adverse outcomes occurred in 25/63 (39.7%) of patients with follow-up. A higher proportion of patients were left with long-term adverse outcomes as injury severity increased (Fisher's exact test, $P < 0.001$). Odds ratio of death following a severe laryngotracheal injury (Schaefer-Fuhrman grade 4 or 5) compared to less severe injury was 7.1 (95% CI = 1.4–35.4). Regarding the seven patients who died, cause of death can be at least partially attributed to laryngotracheal injuries in three patients (2 cardiorespiratory arrests, and 1 aspiration pneumonia); both patients who died of cardiorespiratory arrest suffered complete laryngotracheal separations secondary to homicide and motor vehicle collision (MVC). Three of the remaining patients succumbed to intracranial injuries; the final patient died from intraabdominal sepsis following gastrostomy tube placement for dysphagia in the absence of intracranial injuries, but the association of the laryngotracheal injury with the dysphagia is unclear.

Dysphonia was noted in 12 patients (21.1%), of whom nine were moderate or severe. Among severe laryngotracheal injuries, the odds ratio of developing long-term moderate or severe dysphonia was 17.2 (95% CI = 3.3–91.1). Long-term swallowing dysfunction was identified in eight of the 55 patients (14.5%). Transient dysphagia detected by FEES or MBS in two patients resolved in one and the other was lost to follow-up. After excluding patients with traumatic brain injuries, odds ratios surprisingly suggest that a patient is less likely to develop dysphagia following severe laryngotracheal injury than a less severe injury (OR = 0.12, 95% CI = 0.017–0.87). Minimal overlap existed between patients with long-term adverse outcomes: One patient with dysphagia was dysphonic (mild), and two patients with dyspnea were dysphonic (moderate and severe).

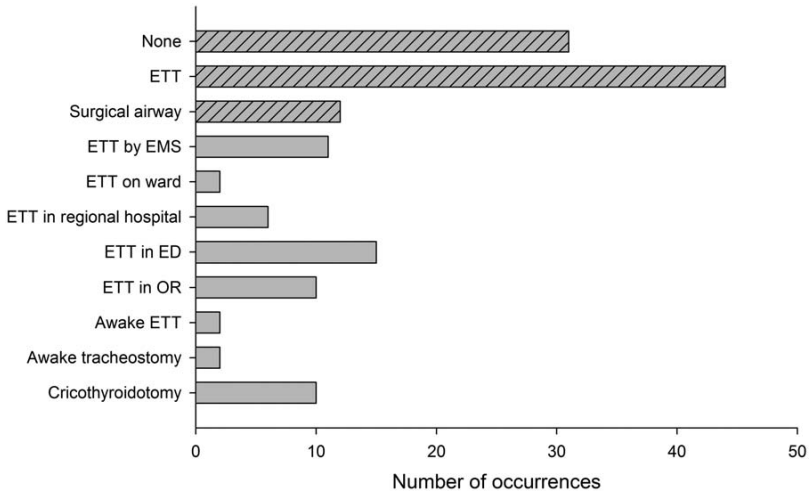

Fig. 3. Methods of initial airway management and intervention. Endotracheal tube intubation and surgical airway are subdivided based on method. ED = emergency department; EMS = emergency medical services; ETT = endotracheal tube; OR = operating room.

Tables (III–VI) contain bivariate analyses of individual factors and their associations with poor outcomes. Again, clinically relevant factors statistically associated with good or poor outcomes were subjected to multivariate regression analysis (Table XI), which found that only coexisting intrathoracic injuries were significantly associated with poor outcomes. Intracranial and cervical spine injuries approached significance for poor outcomes. No factors were statistically associated with good outcomes.

DISCUSSION

Results from this large population-based study demonstrated a higher incidence of laryngotracheal trauma than previously reported, occurring in 1/2422 emergency department visits and 1/1019 hospital admissions. Among these patients, 36.7% experienced an adverse outcome. Long-term dysphonia occurred in 21% of patients (16% moderate or severe), nonneurologic dysphagia persisted in 8%, and dyspnea affected 6%. Compared to data shown in previous studies, our population cohort was similar in demographics, mechanisms, and distribution of severity, although a slightly higher proportion of blunt trauma may be present in our population.[19–21]

The appreciably higher incidence of injuries compared to existing literature and the increasing frequency of laryngotracheal injuries are likely linked and multifactorial in origin. One factor affecting our observed injury rate is the accessibility of the flexible nasopharyngoscope, which allows assessment of endolaryngeal injuries in an awake patient. Indeed, our frequency of grade 1 injuries is nearly identical to that presented by Butler et al., which was also conducted in the era of the

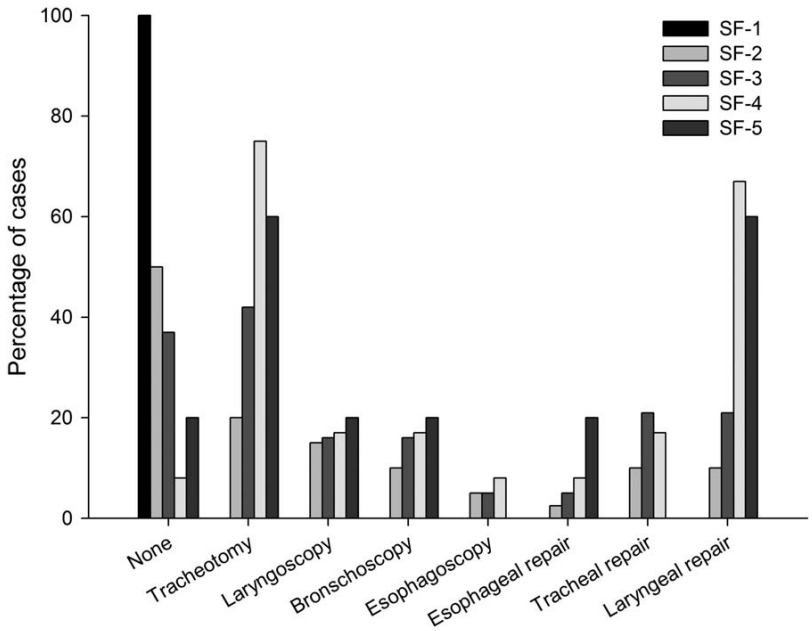

Fig. 4. Acute operative interventions according to laryngotracheal injury severity. S-F = Schaefer-Fuhrman grading scale.

TABLE VII.
Multivariate Regression Analysis of Factors Predictive of Airway Management.

Factor	Airway Management Recommendation	*P* Value	Odds Ratio (95% CI)
Odynophagia	Conservative	**0.002**	0.11 (0.022–0.46)
Sports and recreation	Conservative	0.797	–
Structural framework	Conservative	0.670	–
Stridor	Airway	**0.022**	9.1 (1.36–69.7)
MVC	Airway	**0.040**	7.4 (1.03–45.1)
Respiratory distress	Airway	**<0.001**	N/A (5.52–∞)*
Tracheal injury	Airway	**<0.001**	N/A (4.11–∞)*
Intrathoracic injury	Airway	0.154	–

*All patients presenting with respiratory distress or tracheal injury required airway intervention and preclude odds ratio calculations.
CI = confidence interval; MVC = motor vehicle collision.

flexible scope.[3] Another contributor is the growing use of diagnostic imaging in the initial work-up of potential laryngotracheal injuries. Finally, since we used a population-based database intended to capture all potential injuries, our study may reflect a more accurate injury incidence since this is a single-insurer system responsible for health care provision among all members of the population. Nonetheless, this may remain an underestimate because some patients with grade 1 or 2 injuries may not present to health care providers.

With our large number of patients, we were able to identify factors predictive of patients with laryngotracheal injuries requiring airway capture or surgical intervention to maintain an airway or repair injuries. It is worth emphasizing that patients with respiratory distress are critically unstable and require airway intervention, regardless of the presence of the reassuring features odynophagia or hyoid fracture. The fact that odynophagia is associated with conservative management suggests that more severe injuries are not present. Thus, these factors may prove useful in assessing low acuity patients and guiding management but must be taken in context of the overall clinical picture.

Regarding aerodigestive outcomes, it is little surprise that severe injuries are more likely to cause vocal and airway dysfunction compared to less severe injuries. The role of early versus delayed operative intervention was not possible to address in our study, as only five operative cases began more than 48 hours after hospital presentation. Operating room availability, more pressing critical illness, and delayed diagnoses contributed to the protracted times. Nonetheless, two of these cases developed dysphonia and we must agree that early intervention appears important to maximize outcomes; similarly, dysphonia and dysphagia were overrepresented among patients who did not undergo reparative surgery. Additional factors likely predict adverse outcomes among patients with laryngotracheal injuries, but the small number of these events prevented reaching statistical significance. Intrathoracic injuries probably correlated with adverse outcomes because of the high energy, multisystem injuries endured; while cervical spine and intracranial injuries—although not statistically associated—contribute to dysphagia and dysphonia through cranial nerve deficits, cognitive brain injury, and restricted neck mobility.

All grade 1 injuries were managed nonoperatively, and we identified no adverse aerodigestive outcomes among this group. Regarding grade 2 injuries, however, it is challenging to determine which patients should undergo operative repair; six patients with grade 2 injuries experienced adverse outcomes, all of whom had

TABLE VIII.
Multivariate Regression Analysis of Laryngeal Injuries Predictive of Airway Management.

Factor	Surgical Management Recommendation	*P* Value	Odds Ratio (95% CI)
Hyoid fracture	Nonoperative	**0.033**	0.053 (0.003–0.79)
Supraglottic soft tissue	Nonoperative	0.105	–
Dysphonia	Nonoperative	0.377	–
Odynophagia	Nonoperative	0.064	–
Penetrating injury	Operative	**0.003**	9.60 (2.14–43.0)
Respiratory distress	Operative	**0.005**	13.8 (2.22–85.3)
Self-inflicted	Operative	**0.0047**	N/A (2.2–∞)*
Cricoid fracture	Operative	0.096	–

*All self-inflicted injuries required airway intervention and precluded odds ratio calculations.
CI = confidence interval.

TABLE IX.
Vocal, Deglutition, and Airway Outcomes Sorted According to Injury Severity.

Vocal Outcomes					
		Voice function (% affected)			
			Dysphonic		
Injury severity	Number (% follow-up)	Normal	Mild	Moderate	Severe
1	10	10	0	0	0
2	25	22	1	2	0
3	11	9	1	0	1
4	9	4	1	2	2
5	2	0	0	1	1
Total	57/83* (68.7)	45 (78.9)	3 (5.3)	5 (8.8)	4 (7.0)

Deglutition Outcomes					
		Swallowing function (% affected)			
		Short-term		Long-term	
Injury severity	Number (% follow-up)	Normal	Dysphagia	Normal	Dysphagia
1	8	8	0	8	0
2	26	21	5	21	5
3	11	9	2	9	2
4	8	5	3	7	1
5	2	2	0	2	0
Total	55/84† (65.5)	45 (81.8)	10 (18.2)	47 (85.5)	8 (14.5)

Airway Outcomes			
		Long-term dyspnea (% affected)	
Injury severity	Number (% follow-up)	Absent	Present
1	10	10	0
2	23	22	1
3	9	9	0
4	8	7	1
5	2	1	1
Total	52/84† (61.9)	49 (94.2)	3 (5.8)

*Five patients with immediate or early death and one patient rendered aphonic were excluded in addition to patients lacking follow-up data.
†Five patients with immediate or early death were excluded in addition to patients lacking follow-up data.

delayed or no surgical intervention. Three were dysphonic and three were dysphagic, although one patient's dysphagia was attributed to neurologic impairment. None of the dysphagic patients complained of dysphagia or odynophagia on presentation. Two of the three patients with grade 2 injuries who developed long-term dysphonia presented dysphonic; yet 17 of 40 patients with grade 2 injuries presented with dysphonia. While this represents the most common presenting symptom, it is not universal. Operative laryngoscopy may be appropriate in patients with grade 2 injuries and vocal symptoms to rule out endolaryngeal injuries that may not be otherwise detected, and they should be cautioned for the potential of long-term voice change. Although we had 40 patients with grade 2 injuries in our series, the small number of adverse outcomes prevented analysis of features predictive of long-term sequelae.

Our study's limitations relate to the retrospective design and to the incorporation of centralized databases. Although health records clearly describe injuries,

TABLE X.
Summary of Adverse Aerodigestive Outcomes Among Laryngotracheal Injury Patients.

Outcome	Number With Follow-Up (%)	Number Affected (%)	Odds Ratio (95% CI)
Death	89 (100%)	7 (7.9)	7.1 (1.4–35.4)
Dysphonia			
Any	57 (68.7)	12 (21.1)	14.4 (3.1–66.9)
Moderate to severe	57 (68.7)	9 (15.8)	17.2 (3.3–91.1)
Dysphagia			
Short-term	55 (65.5)	10 (18.2)	N/A
Long-term (including TBI)	55 (65.5)	8 (15.4)	N/A
Long-term (excluding TBI)	50 (63.8)	4 (7.8)	0.060 (0.0054–0.66)
Dyspnea	52 (61.9)	3 (5.8)	10.3 (0.83–127)
Any adverse outcome	63 (70.9)	25 (39.6)	14.0 (3.5–56.8)

Odds ratios were determined for severe laryngotracheal injuries (Schaefer-Fuhrman Score ≥ 4) compared to less severe injuries.
Individual outcomes do not add up to total number affected by any adverse outcome due to multiple comorbidities in patients.
CI = confidence interval; TBI = traumatic brain injury.

grading errors may occur upon review. Furthermore, the Schaefer-Fuhrman scale requires greater judgment when grading mucosal injury severity compared to the more objective evaluation of framework fractures, and this provides fluidity classifying injuries as grade 2 versus grades 1 or 3. This may lead to a regression to the mean bias and a higher proportion of grade 2 injuries. However, total incidence remains unaffected by this factor, as all included patients had documented injuries. Because data contained within the databases are collected and stored by nonmedical personnel, data accuracy depends on extraction from health care provider records, which can be incomplete or illegible. This may decrease our observed incidence by omitting potential subjects, but our attempt to capture all cohort members by reviewing all traumatic neck injuries would mitigate this effect. Conversely, for coding errors falsely suggesting a laryngotracheal injury, our thorough review of health records prevented inadvertent inclusion of noninjuries. Finally, identifying factors predictive of management and outcomes retrospectively is correlative but not causative.

CONCLUSION

In summary, our results show that laryngotracheal injuries are considerably more common than previously reported. Although many of these injuries do not require operative intervention, awareness of the injury with complete, prompt work-up and evaluation are important in order to implement timely, appropriate management. Patients and health care providers should be aware of the high frequency of long-term sequelae associated with laryngotracheal injuries.

TABLE XI.
Multivariate Regression Analysis of Associated Injuries Predictive of Airway Management.

Factor	Outcome Association	*P* Value	Odds Ratio (95% CI)
Intrathoracic injury	Poor	**0.037**	5.43 (1.11–26.6)
Intracranial injury	Poor	0.062	–
Cervical spine injury	Poor	0.075	–
Odynophagia	Good	0.186	–

CI = confidence interval.

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