Contemporary assessment of laryngotracheal trauma

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Objectives: Laryngotracheal trauma is a rare and potentially deadly spectrum of injuries. We sought to characterize the contemporary mechanisms, diagnostic modalities, and outcomes common in laryngotracheal trauma today.

Methods: We performed a retrospective analysis of all laryngotracheal trauma cases at 2 major metropolitan hospitals between 1996 and 2004, detailing mechanisms, associated injuries, diagnostic modalities, and outcomes of laryngotracheal trauma.

Results: We identified 71 patients with a mean age of 32.8 ± 13.3 years (range, 15-71 years). In our series penetrating trauma was the cause in 73.2% of patients; however, blunt trauma had a significantly higher mortality (63.2% vs 13.5%, respectively; $P < .0001$). Blunt mechanisms involved older patients (38.5 ± 15.2 years vs 30.1 ± 11.9 years, $P = .017$), and these patients were more likely to require emergency airways than those with penetrating trauma (78.9% vs 46.2%, $P = .017$). The requirement of an emergency airway was an independent predictor of mortality ($P = .0066$).

Conclusion: Laryngotracheal trauma is a deadly spectrum of injuries with a mortality of 26.8%. Blunt mechanisms are decreasing in frequency. This might reflect improvements in automobile safety. Additionally, violent crime is on the increase, producing penetrating injuries with increasing frequency. The most fundamental intervention for patients with laryngotracheal injury is airway control. Either routine intubation or a tracheostomy can secure the airway. Blunt trauma and the requirement of an emergency airway are independent predictors of mortality. Laryngotracheal trauma requires prompt recognition, airway protection, and skillful management to lessen the mortality of this deadly spectrum of injuries.

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Laryngotracheal trauma (LTT) is a rare and life-threatening spectrum of injuries. Schaefer¹ reported an incidence of 1 in 30,000 emergency visits over a 27-year period for blunt injuries alone. Bent and colleagues² reported an incidence of 1 in 5000 emergency department visits in 1987 for both blunt and penetrating LTT. In a population-based study by Jewett and associates,³ an incidence of 1 in 137,000 inpatients was identified. Gussack and coworkers⁴ reported an incidence of less than 1% of trauma cases. Blunt LTT has a mortality of up to 20%, and penetrating trauma has a mortality rate up to 40%.^{5,6} Successful treatment depends on early diagnosis, complete evaluation of associated injuries, skillful management of the airway, and proper treatment of each injury.^{7,8}

Because of the rare occurrences of these injuries, few reports exist that characterize contemporary injury patterns and management techniques. Schaefer¹ reviewed 139 patients over a 27-year period in 1992, and Francis and colleagues⁹

Figure 1. Mechanism of injury for blunt and penetrating LTT.

recently published a report that identified 23 patients over a 6-year period. Our review details contemporary mechanisms, diagnostic modalities, and outcomes of LTT in an urban population.

Patients and Methods

A total of 44,684 patients with trauma were admitted to 2 level I trauma centers, Parkland Memorial Hospital and Wilford Hall Medical Center, between January 1996 and December 2003. We performed a retrospective analysis of the trauma databases at each hospital within this period to identify all patients with LTT. Isolated injury below the sternal notch excluded patients from the study. We identified and reviewed 71 cases to determine the mechanisms of injury, diagnostic procedures used, associated injuries, and outcomes. There were 56 (78.9%) male and 15 (21.1%) female patients with a mean age of 32.8 ± 13.3 years (range, 15-71 years). We classified patients into 2 groups on the basis of mechanism, either blunt or penetrating. The blunt group consisted of 19 patients, and the penetrating group contained 52 patients. The follow-up period ranged from 6 months to 8 years. We assessed outcomes in terms of mortality, voice ability, and airway patency. Voice evaluation was scored on individual patients with the following grades: good voice resembled the voice before injury, fair voice differed but was still functional, and poor voice represented aphonia, whisper, or unintelligible speech.^{2,9,10} The airway was graded as good if the patient had a normal airway or if the patient could be decannulated and poor if the patient needed a tracheostomy for airway control.⁷

Categorical variables were analyzed with the χ^2 and Fisher exact tests as appropriate in contingency tables, whereas Student *t* tests and Mann-Whitney *U* tests were performed as appropriate for comparison of continuous variables. The logistics regression model was applied for univariate and multivariate analyses to confirm the prognostic effect of the factors on mortality. Data were

TABLE 1. Characteristics of patients with laryngotracheal trauma according to trauma type

Variables	n	Blunt trauma, n = 19 (%)	Penetrating trauma, n = 52 (%)	P value
Age (y)	71	38.5 ± 15.2	30.1 ± 11.9	.017
Age (y)				
Less than median age (32 y)	37	5 (26.3)	32 (61.5)	
Great than median age (32 y)	34	14 (73.7)	20 (38.5)	.015
Sex				
Male	56	14 (73.7)	42 (80.8)	
Female	15	5 (26.3)	10 (19.2)	.525
Location				
Larynx	15	4 (21.1)	11 (21.2)	
Trachea	26	2 (10.5)	24 (46.2)	
Larynx + trachea	30	13 (68.4)	17 (32.6)	.011*
Associated injuries				
Head trauma	6	3 (30)	3 (11.6)	
Vascular injury	8	3 (30)	5 (19.2)	
Esophageal injury	5	1 (10)	4 (15.4)	
Chest trauma	11	2 (20)	9 (34.6)	
Combined injury	6	1 (10)	5 (19.2)	
Associated injuries				
Present	36	10 (52.6)	26 (50)	
Absent	35	9 (47.4)	26 (50)	.844
Emergency airway requirement				
Present	39	15 (78.9)	24 (46.2)	
Absent	32	4 (21.1)	28 (53.8)	.017
Voice ability				
Poor	2	1 (14.3)	1 (2.2)	
Fair	7	1 (14.3)	6 (13.3)	
Good	43	5 (71.4)	38 (84.5)	.298†
Airway patency				
Poor	2	1 (14.3)	1 (2.2)	
Good	50	6 (85.7)	44 (97.8)	.253
Mortality				
Dead	19	12 (63.2)	7 (13.5)	
Alive	52	7 (36.8)	45 (86.5)	<.0001

*P value on the basis of injury site (larynx or trachea vs larynx and trachea). †P value on the basis of voice ability (good vs fair-poor).

expressed as means $\pm$ standard deviation. All statistical analyses were performed with the Statistical Package for Social Sciences (SPSS, version 12.0, Chicago, Ill).

Results

Blunt Trauma Group

There were 14 male and 5 female patients in the blunt trauma group with a mean age of 38.5 ± 15.2 years (range, 16-69 years). Causative factors included 9 (47.4%) steering-wheel collisions, 4 (21.1%) hanging injuries, and 2 (10.5%) clothesline mechanisms (Figure 1). In this series 13 (68.4%) cases involved the larynx and the trachea, whereas only 4

Figure 2. Signs and symptoms of patients with LTT with respect to blunt trauma and penetrating trauma groups. *White columns, Blunt (n = 19); black columns, penetrating (n = 52).*

(21.1%) patients had isolated laryngeal injury, and 2 (10.5%) patients had isolated tracheal injury (Table 1).

Eleven (57.9%) of the patients with blunt LTT presented in cardiopulmonary arrest (CPA). Ten of these patients were involved in steering-wheel collisions, and only 1 of these patients was successfully resuscitated. Seven (36.8%) patients had cervical ecchymoses, and 5 (26.3%) patients had neurologic deficits. Apnea occurred in 4 (21.1%) patients, stridor or wheezing occurred in 3 (15.8%) patients, and hoarseness occurred in 2 (10.5%) patients (Figure 2).

Fifteen (78.9%) of the 19 patients required an emergency airway. Fourteen patients were intubated, and 1 required a cricothyroidotomy. One patient who was initially intubated required a subsequent tracheostomy for prolonged airway control. These patients required mechanical ventilation for a mean of 1.2 ± 1.2 days (range, 6 hours to 3 days).

Eight (42.1%) patients with blunt LTT presented with other injuries. Two patients had cervicothoracic vascular injuries, and 2 others had closed-head injuries (10.5% each). One (5.3%) patient presented with combined vascular and closed-head injuries. Two (10.5%) patients had nonesophageal thoracic injuries, and 1 (5.3%) patient had an esophageal injury.

Computed tomography (CT) detected laryngotracheal injuries in 4 (21.1%) patients. Fiberoptic laryngoscopy was diagnostic in the 2 (10.5%) patients who had isolated laryngeal injuries. A combination of both CT scanning and fiberoptic laryngoscopy allowed diagnosis in 2 (10.5%) patients with LTT.

Only 4 of the 19 patients required operative intervention. Two patients required tracheal repair, and a third required laryngeal repair. The fourth patient required an operative tracheostomy. Three other patients were noted to have contusions on diagnostic testing.

Seven (36.8%) patients survived blunt LTT in this series. Ten (52.6%) of the patients presented in CPA and did not respond to Advanced Trauma Life Support/Advanced Cardiac Life Support (ATLS/ACLS) protocols. Two additional patients died within 24 hours of admission of other complications. Good voice quality was present in 5 (71.4%) of the 7 surviving patients, and a good airway was achieved in 6 (85.7%) patients.

Penetrating Trauma Group

There were 42 male and 10 female patients in the penetrating trauma group with a mean age of 30.1 ± 11.9 years (range, 15-71 years). The most common causative factors

were gunshot wounds in 26 (50.0%) patients and stab wounds in 24 (46.2%) patients (Figure 1). Two other patients sustained injuries from glass shards when windows shattered. The trachea was the most common site for penetrating mechanisms, with 24 (46.2%) patients sustaining injuries to this location. Seventeen (32.6%) patients had injuries to both the larynx and the trachea. Only 11 (21.2%) patients had isolated laryngeal injuries.

The most common findings were 12 (23.1%) patients with cervical ecchymoses or hematomas, 12 (23.1%) patients with stridor or wheezing, 10 (19.2%) patients who presented in CPA, and 9 (17.3%) patients with hemoptysis. Neurologic deficits and aphonia were each present in 8 patients (15.4% each). Seven (13.5%) patients had cervical crepitus, and 6 (11.5%) patients had subcutaneous emphysema (Figure 2).

Approximately half of the 52 patients with penetrating injuries required emergency airways through intubation ($n = 20$), tracheostomy ($n = 3$), or cricothyroidotomy ($n = 2$). Twelve of the patients initially endotracheally intubated or needing cricothyroidotomies required revision to formal tracheostomies in the operating room. An additional 7 patients required operative tracheostomies. Two patients needed emergency cricothyroidotomies in the operating room. One was previously endotracheally intubated, and the other required no initial emergency room airway. Patients with penetrating LTT who necessitated artificial airways required mechanical ventilation for 8.7 ± 7.6 days (range, 3 hours to 44 days).

A total of 26 (50.0%) patients had associated injuries. The 2 most common injuries were thoracic trauma in 12 (23.1%) patients and cervicothoracic vascular injuries in 10 (19.2%) patients. Five (9.6%) patients had combinations of closed-head injuries, vascular injuries, esophageal injuries, or nonesophageal thoracic trauma. Both gunshot wounds and stab wounds caused vascular injuries in 5 patients (9.6% each). Thoracic trauma was present in 5 (9.6%) patients with gunshot wounds and 7 (13.5%) patients with stab wounds.

Four diagnostic procedures were used in fairly even ratios in patients with penetrating mechanisms. Esophagogastroduodenoscopy, barium swallow, or fiberoptic laryngoscopy was performed in 17 patients, whereas CT scanning was used in 15 patients. Intraoperative esophagoscopy was used in 11 patients for the diagnosis of esophageal perforation.

Forty-four (84.6%) patients with penetrating LTT underwent operative management of their injuries. Repair of the larynx, trachea, or both occurred in 40 patients. On exploration, the other 4 patients had penetrating neck injuries, with bruising in the laryngotracheal region requiring no formal repair.

TABLE 2. Characteristics of patients with laryngotracheal trauma according to mortality

Variables	n	Dead, n = 17 (%)	Alive, n = 43 (%)	P value
Age (y)	71	34.4 $\pm$ 14.4	31.6 $\pm$ 12.9	.439
Age (y)				
Less than median age (32 y)	37	9 (47.4)	28 (53.8)	
Greater than median age (32 y)	34	10 (52.6)	24 (46.2)	.629
Sex				
Male	56	17 (89.5)	39 (75)	
Female	15	2 (10.5)	13 (25)	.324
Trauma type				
Blunt	19	12 (63.2)	7 (13.5)	
Penetrating	52	7 (36.8)	45 (86.5)	<.0001
Location				
Larynx	15	4 (21.1)	11 (21.2)	
Trachea	26	3 (15.8)	23 (44.2)	
Larynx + trachea	30	12 (63.1)	18 (34.6)	.056*
Associated injuries				
Head trauma	6	3 (27.3)	3 (12)	
Vascular injury	8	2 (18.2)	6 (24)	
Esophageal injury	5	1 (9.1)	4 (16)	
Chest trauma	11	2 (18.2)	9 (36)	
Combined injury	6	3 (27.3)	3 (12)	
Associated injuries				
Present	36	11 (57.9)	25 (48.1)	
Absent	35	8 (42.1)	27 (51.9)	.464
Emergency airway requirement				
Present	39	18 (94.7)	21 (40.4)	
Absent	32	1 (5.3)	31 (59.6)	<.0001

*P value on the basis of injury site (larynx or trachea vs larynx and trachea).

There was an 86.5% survival for patients with penetrating neck injuries. Forty-five patients were followed up for voice and airway quality. Thirty-eight (84.4%) patients had good voices, and 44 (97.8%) patients had good airways.

Comparison of Blunt and Penetrating LTT

The mean age of patients in the blunt trauma group was 38.5 ± 15.2 years, whereas in the penetrating trauma group it was 30.1 ± 11.9 years ($P = .017$, Table 1). In addition, trauma location ($P = .011$), emergency airway requirement ($P = .017$), and mortality rate (63.2% [blunt] vs 13.5% [penetrating], $P < .0001$) differed significantly between the 2 groups (Table 2). Significant univariate predictors of mortality were blunt trauma type ($P = .0001$), emergency airway requirement ($P = .0021$), and trauma localization (larynx plus trachea vs either larynx or trachea, $P = .0352$; Table 3). However, multivariate analysis identified only blunt trauma ($P = .0089$) and need of an emergency airway ($P = .0066$) as independent predictors of mortality.

TABLE 3. Univariate and multivariate analysis of 71 patients by a logistic regression model according to mortality

Variable	Relative risk	95% confidence interval	P value
Age (y)			
Greater than median age vs less than median age	1.296	0.452-3.714	.6290
Sex			
Male vs female	2.830	0.575-13.930	.2006
Trauma type			
Blunt vs penetrating	11.020	3.234-37.552	.0001
Associated injuries			
Present vs absent	1.485	0.514-4.289	.4650
Emergency airway requirement			
Present vs absent	26.569	3.291-214.469	.0021
Location			
Larynx vs trachea	2.787	0.529-14.668	.2262
Location			
Larynx + trachea vs larynx or trachea	3.237	1.085-9.661	.0352
Trauma type			
Blunt vs penetrating	7.554	1.661-34.358	.0089
Emergency airway requirement			
Presence vs absence	20.212	2.308-176.970	.0066
Location			
Laryngotracheal vs larynx or trachea	1.425	0.328-6.178	.6360

Discussion

LTT is a rare and potentially lethal spectrum of injuries that might be missed without a high index of suspicion. The incidence of LTT in our series is 1 in 15,000 emergency department admissions and represents 0.2% of all trauma admissions over an 8-year period. Historically, most cases of LTT resulted from blunt-force mechanisms to the cervical region.^{8,9} However, within the last decade, there appears to be a shift in the mechanism of LTT to penetrating injuries (Figure 3).^{2,3,5,6,8,9,11-16} The Federal Bureau of Investigation reports that Dallas, Texas, has the highest crime rate in the nation among cities with populations of greater than 1 million persons, and Dallas also ranks third in the nation in total murder rate.¹⁷ These facts suggest that penetrating trauma is on the increase in our community. Conversely, decreased rates of blunt LTT might reflect improved automobile safety, lower speed limits, and the mandatory use of safety belts.² In the National Highway Safety Traffic Administration's *Traffic Safety Facts: 2002*, the number of injuries caused by automobile accidents has steadily decreased over a 7-year period starting in 1995.¹⁸ This might contribute to the decrease in the incidence of blunt LTT.

Previous reviews of LTT report that the mean age of patients ranges from 26 to 34 years.^{2,11} The mean age within our series is 32.8 ± 13.3 years. The average age for patients with a penetrating mechanism is 30 years, which is lower than what Grewal and coworkers¹⁹ stated in their series. However, the percentage of male and female patients is not different from that seen in previous series.¹⁹ In this series we demonstrate a significant correlation between the mechanism of trauma (blunt vs penetrating) and age ($P = .017$); however, age is not a significant factor in mortality ($P = .6290$).

The most fundamental intervention for patients with laryngotracheal injury is airway control. Either routine intubation or a tracheostomy can secure the airway. A tracheostomy provides space with which to examine the site of injury both at the site and from above with direct laryngoscopy. Endotracheal intubation might render further examination of the injury difficult and might aggravate an existing laryngeal injury. However, there is controversy regarding the best method of gaining a secure airway. Schaefer¹ avoided intubation in these patients and recommended a tracheostomy using local anesthesia. Similarly, Fuhrman and associates²⁰ reported that a tracheostomy should be the only method of airway control used in LTT. In contrast, Gussack and coworkers⁴ argued that endotracheal intubation can safely manage the airway if performed by experienced personnel under direct visualization with a small endotracheal tube. Blind intubation should not be used in patients with potential LTT because of the risk of complete airway obstruction. The Ryder Trauma Center uses specific guidelines for penetrating neck injuries. They suggest using awake fiberoptic intubation, rapid-sequence fiberoptic intubation, rapid-sequence induction, or awake orotracheal intubation depending on the emergency need for an airway. If any of these methods fail, a surgical airway through a cricothyroidotomy should be established.²¹ This study demonstrates that emergency endotracheal intubation can be done safely. This can be followed by an operative tracheostomy in patients who require prolonged airway control. In this series 39 (54.9%) of the 71 patients with LTT required an emergency airway. Forty-eight percent of patients underwent initial orotracheal intubation, whereas tracheostomy and cricothyroidotomy were performed in 4% each. Patients with blunt LTT required an emergency airway in 78.9% of cases, whereas those with penetrating LTT required one in 46.2% ($P = .017$). Intubation was successful in 14 of the 15 patients in the blunt trauma group and 20 of the 24 patients in the penetrating trauma group. Moreover, univariate ($P = .0021$) and multivariate ($P = .0066$) analyses identified the requirement of an emergency airway as a significant predictor of mortality.

Figure 3. Review of LTT series with respect to blunt trauma and penetrating trauma groups. White columns, Blunt; black columns, penetrating.

There are several diagnostic modalities, in addition to a good physical examination, available for the workup of these patients. Most authors recommend the use of flexible fiberoptic laryngoscopy and CT analysis as excellent adjuvant procedures for the evaluation of laryngotracheal injuries.^{4,6-8,22} Flexible fiberoptic laryngoscopy permits evaluation and often correct assessment of the extent of the laryngeal injury.¹ Laryngoscopic findings in our study included laceration of the thyroid cartilage, laryngeal tear, laryngeal edema, and hematoma. CT scanning of the neck is useful in patients without hard evidence of LTT. The CT might be helpful in determining the tract of penetrating trauma and identifying those patients who might benefit from further endoscopic or contrast swallow studies.^{7,22} CT findings of LTT included fractures of the cricoid or laryngeal cartilage, subcutaneous hematoma, subcricoid edema, and subcutaneous air surrounding the trachea. CT scanning and flexible fiberoptic laryngoscopy are the 2 most common diagnostic tools in our patients with LTT. Esophagogastroduodenoscopy and barium swallow are 2 additional methods for investigation of the upper aerodigestive tract in patients suspected of having LTT.

The prognosis of laryngotracheal injuries depends primarily on the presence of other major associated injuries.

Injuries with sufficient magnitude to cause severe laryngotracheal damage might also cause injury to the esophagus, cervical spine, and/or vascular structures. In hemodynamically stable patients a detailed examination and appropriate adjuvant diagnostic studies must be pursued.⁸ Esophagoscopy and contrast swallow studies are useful in determining the presence of an esophageal injury. If esophagoscopy cannot rule out esophageal trauma with certainty, contrast swallow might be necessary.^{2,8,22}

Bent and colleagues² reported esophageal injuries in 14% of patients with LTT, closed-head injuries in 28%, and spine trauma in 14%. In the series of Mathisen and Grillo,⁸ thoracic trauma and closed-head injuries were the most common associated injuries. Grewal and associates¹⁹ reported that the incidence of associated esophageal injuries was 19% in patients with penetrating LTT. Vascular and esophageal injuries were the most common associated injuries in the series by Gussack and coworkers.⁴ Our results demonstrate that thoracic trauma (15.5%) and vascular injuries (11.3%) are the most common associated injuries, followed by closed-head trauma (8.5%).

Another controversy in the management of LTT is the timing of the operative exploration. Some authors recommend delaying intervention to allow edema to sub-

side.^{23,24} However, the consensus is that results are better if patients are treated early. Most trauma centers recommend operating within 24 hours if feasible.^{1,12,25} In our series all patients who required operative intervention underwent exploration within 24 hours of admission.

Poor voice quality and poor airway patency were each present in 2 patients in long-term follow-up. This review demonstrates no significant correlation between trauma mechanism and voice quality ($P = .298$) or airway patency ($P = .253$). Additionally, we do not find a significant correlation between the presence of an emergency airway and poor voice quality ($P = .181$, data not shown).

LTT remains a rare and life-threatening set of injuries with serious complications. In this series 26.8% of patients with LTT died (blunt injury [63.2%] vs penetrating injury [13.5%]). It is easily overlooked and difficult to diagnose. To improve the dismal outcome of these patients, practitioners must focus on early diagnosis, appropriate management of the airway, identification and treatment of associated trauma, and prompt repair of the injury. Therefore trauma surgeons, thoracic surgeons, otolaryngologists, anesthesiologists, and emergency physicians should be well educated in the management of laryngotracheal injuries.

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