Airway management changes associated with rising radiologic incidence of external laryngotracheal injury

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This article was presented at the Canadian Society of Otolaryngology annual meeting held May 10–13, 2014, Ottawa, Ont.

Accepted Sept. 18, 2017

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DOI: 10.1503/cjs.012216

Background: Traumatic laryngeal injuries are uncommon life-threatening injuries that require prompt, rational management of a potentially precarious airway. It is unclear whether the current incidence of laryngotracheal injury is due to enhanced injury detection or increased occurrence. The objective of this study was to evaluate the relations between diagnostic imaging with both initial airway management and surgical treatment in patients with external laryngotracheal injuries (ELTIs) in Alberta.

Methods: In this large-scale population-based analysis, we used regional health databases containing inpatient admissions, emergency department visits and trauma service activations employing International Classification of Diseases diagnostic codes to identify all ELTIs diagnosed from Apr. 1, 1995, to Dec. 31, 2011, in adults (age ≥ 16 yr). We evaluated health records and diagnostic imaging for injury features, airway management, operative interventions and hospital length of stay (LOS).

Results: Eighty-nine patients met the inclusion criteria. The incidence of ELTIs increased over time, paralleling a rise in detection during the period incorporating greater computed tomography (CT) use ($p = 0.002$). Endotracheal tube intubation was performed in 8/30 cases (27%) in the pre-CT era, compared to 38/59 cases (64%) in the post-CT era ($p = 0.001$); the use of surgical intervention remained consistent. The largest contributors to increased endotracheal tube placements were the emergency department and emergency medical services. No change in survival was detected, but mean LOS among patients admitted for minor, isolated ELTIs increased by 2.3 (95% confidence interval 0.14–4.8) days ($p = 0.06$), mostly for patients admitted under critical care for mechanical ventilation.

Conclusion: Management of ELTIs shifted from predominantly conservative airway monitoring to endotracheal tube intubation over the study period in spite of no clinically significant change in injury severity or operative intervention frequency. The location of endotracheal tube placement suggests less comfort with ELTI among first-responder and emergency personnel.

Contexte : Les lésions traumatiques du larynx sont des blessures rares qui peuvent être mortelles et nécessitent une prise en charge rapide et efficace, en raison de l'état potentiellement précaire des voies respiratoires. On ignore si l'incidence actuelle des lésions laryngo-trachéales est attribuable à une amélioration de la détection ou à une augmentation de la fréquence réelle. Cette étude avait pour but d'évaluer le lien entre l'imagerie diagnostique, et la prise en charge initiale des voies respiratoires ainsi que le traitement chirurgical chez des patients ayant subi des lésions laryngo-trachéales externes (LLTE) en Alberta.

Méthodes : Dans le cadre de cette analyse de grande envergure basée sur une population, nous avons interrogé des bases de données régionales sur les hospitalisations, les consultations aux services d'urgence et la prestation de services de traumatologie. Nous nous sommes servis des codes diagnostiques de la Classification statistique internationale des maladies pour repérer tous les cas de LLTE diagnostiqués entre le 1^{er} avril 1995 et le 31 décembre 2011 chez des adultes (16 ans et plus). Nous avons examiné les dossiers de santé et les résultats d'imagerie diagnostique pour en extraire des données sur les caractéristiques des lésions, la prise en charge des voies respiratoires, les interventions chirurgicales et la durée de séjour à l'hôpital.

Résultats : Au total, 89 patients répondaient aux critères d'inclusion. L'incidence des LLTE a augmenté au fil du temps; en parallèle, l'utilisation répandue de la tomographie par ordinateur a entraîné une augmentation de la détection de ces lésions ($p = 0,002$).

Une intubation trachéale a été réalisée chez 8/30 patients (27 %) pendant la période pré-tomographie, et chez 38/59 patients (64 %) pendant la période post-tomographie ($p = 0,001$); le recours à la chirurgie est demeuré constant. L'augmentation du nombre d'intubations est principalement attribuable aux interventions effectuées par le personnel ambulancier et par les services d'urgence. Aucun changement du taux de survie n'a été enregistré; toutefois, la durée de séjour moyenne des patients hospitalisés en raison de LLTE mineures et isolées a augmenté de 2,3 jours (intervalle de confiance à 95 % : 0,14–4,8; $p = 0,06$), surtout pour les patients admis aux soins intensifs pour recevoir une ventilation mécanique.

Conclusion : Durant la période à l'étude, la prise en charge des LLTE est passée d'un suivi essentiellement conservateur des voies respiratoires à la prépondérance de l'intubation trachéale, bien qu'aucun changement significatif n'ait été observé quant à la gravité des lésions ou à la fréquence des interventions chirurgicales. Le contexte où ont lieu les intubations laisse croire que le personnel ambulanciers et les premiers intervenants sont moins à l'aise de prendre en charge les LLTE.

Laryngotracheal trauma is a potentially devastating injury requiring careful management to prevent catastrophic complications. Traumatic laryngotracheal injuries can be classified as external or internal and as due to blunt or penetrating mechanisms. Among external laryngotracheal injuries (ELTIs), a severity classification from 1 to 4 defined by Schaefer and Close¹ describing mucosal and structural injuries (later modified by Fuhrman and colleagues² to include complete laryngotracheal separation) provides the most commonly used grading system.

Because the larynx and trachea are protected by surrounding bony structures and numerous soft-tissue suspensions, injuries to the laryngotracheal apparatus are considered infrequent, occurring in 1/14 583–1/137 000 of emergency department visits.^{1,3,4} However, mechanisms of injury involving high velocity, high impact or direct trauma to the neck increase the likelihood of laryngotracheal trauma.⁵ Although public safety interventions such as seat belts have reduced the number of blunt ELTIs occurring during motor vehicle collisions, increases in interpersonal violence have potentially negated these gains.^{4,6,7} We previously showed increasing incidence of ELTIs in a high-volume Canadian trauma centre, which may represent heightened detection secondary to increased use of diagnostic imaging rather than injuries requiring intervention.⁸

To further investigate the impact of diagnostic imaging on ELTI diagnosis and management, we performed a study to assess injury recognition modality, airway management and outcomes in patients with ELTIs in Alberta. Using a data storage system capturing all patient encounters in the province, we employed a population-based approach to better evaluate these variables.

METHODS

Patient identification

We performed a retrospective cohort study of all adults (age ≥ 16 yr) with ELTIs between Apr. 1, 1995, and Dec. 31, 2011, in Alberta using the Southern Alberta

Trauma Database and the Analytics department of Alberta Health Services. The former contains prospectively collected data for all patients with severe injuries (Injury Severity Score ≥ 12) who were admitted to the adult level 1 tertiary care trauma hospital responsible. Alberta Health Services prospectively records all emergency department visits and in-patient admissions at health care facilities that it operates. We queried the databases independently for all patients with ELTIs documented as a primary or secondary diagnosis, or high likelihood of ELTI due to neck trauma, using International Classification of Diseases, Ninth revision (ICD-9) and ICD-10 codes involving the neck and laryngeal structures (Table 1). For both databases, data are collected prospectively, with preselected information recorded after patient discharge or death.

Database analysis produced potential patients' names, age, unique identifying numbers, primary and secondary diagnoses, presentation date and time, interventions, and discharge date and disposition. Following cohort identification, we cross-referenced all patients between databases by name and unique identifying number to eliminate duplicates and to populate a list of patients with potential ELTI. We refined the patient cohort following inclusion of confirmed ELTI through diagnostic imaging, clinical examination (direct examination or flexible nasopharyngo-

Table 1. International Classification of Diseases, ninth revision (ICD-9) and ICD-10 diagnostic codes used in cohort identification

ICD 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

laryngoscopy) or operative identification of injury. Patients were excluded 1) if the initial presentation, diagnosis and primary management were performed in hospitals outside Calgary, 2) in the absence of documented ELTI, 3) if they had endolaryngeal trauma such as intubation or ingestion of a caustic substance, 4) if they had ELTI secondary to resuscitation or 5) if no visit corresponding to a patient's unique identifying numbers was associated with the presentation date.

Injury classification

We defined ELTIs to include all injuries involving bony, cartilaginous or soft-tissue structures extending from the superior boundary of the supraglottis (tip of the epiglottis, including 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

We reviewed electronic and paper records (emergency medical services records, emergency department notes, trauma team flow sheets, intensive care unit transfer summaries, discharge summaries, death summaries, medical examiner records, specialist consultation records, diagnostic imaging reports, physician and nurse notes, and operative notes) associated with the encounter. We defined 2 periods to account for the greater use of computed tomography (CT) in current trauma practice: the pre-CT era (2003 and earlier) and the post-CT era (after 2003). This corresponds to the introduction of the routine trauma series CT for potential cervical spine or neck injuries in our centre. The modality used to recognize each ELTI was assigned as clinical or diagnostic imaging. We defined the initial airway management method as the first definitive airway technique using a cuffed tube within the trachea or as conservative management not requiring a definitive airway. When comparing outcomes among patients requiring endotracheal tube intubation versus conservative management, we excluded patients requiring emergent cricothyroidotomy or tracheostomy as the primary airway capture method.

Statistical analysis

We performed statistical analysis using SigmaPlot 12.0 (Systat), with descriptive statistics, unpaired *t* tests, 2-way analysis of variance, χ^2 analysis and the Kruskal–Wallis H test determined where applicable. The study received ethics approval from the University of Calgary Conjoint Health Research Ethics Board.

RESULTS

Patient injury characteristics

Eighty-nine patients with documented ELTIs were included for final data analysis. The patients' demographic characteristics and injury features are shown in Table 2. Most (73 [82%]) were men, and the mean age was 37.3 (range 18–80) years. Of the 89 patients, 74 (83%) were admitted, with a mean length of stay (LOS) of 17 days (median 6.5 d). Fig. 1 shows the soft-tissue and framework injuries by laryngeal anatomic subregions; injuries most commonly involved the supraglottis and thyroid cartilages.

Diagnostic modality and intervention

The incidence of ELTIs increased over time, paralleling a rise in detection by diagnostic imaging (Fig. 2). This is attributable to early imaging on patient presentation and stabilization since the routine incorporation of trauma series CT (skull base to fourth thoracic vertebra with dedicated soft-tissue and bone windows) in 2004, illustrated in Fig. 3 by the altered ratio of injuries detected by diagnostic imaging ($p = 0.002$ [χ^2 test], 3 degrees of freedom). The distribution of injury severity shifted following increased CT

Table 2. Patient demographic characteristics and injury features

Characteristic/feature	No. (%) of patients* <i>n</i> = 89
Age, yr	
Mean $\pm$ SD	37.3 $\pm$ 16.2
Median	33.0
Sex	
Male	73 (82)
Female	16 (18)
Otolaryngology consultation	67 (75)
Trauma surgery activation	63 (71)
Admitted	74 (83)
Length of stay, d	
Mean $\pm$ SD	17.1 $\pm$ 28.6
Median	6.5
Initial admitting service	
None	14 (16)
Intensive care unit	54 (61)
Trauma surgery	13 (15)
Otolaryngology	7 (8)
Died before admission	1 (1)
Injury severity, Schaefer–Fuhrman injury grade	
1	13 (15)
2	40 (45)
3	19 (21)
4	12 (13)
5	5 (6)
Comorbid injuries	54 (61)

SD = standard deviation.

*Except where noted otherwise.

Fig. 1. Distribution of external laryngotracheal injuries according to soft-tissue and structural framework subsites. Images adapted from © Primal Pictures. All rights reserved. Primal Pictures, an informa business (www.primalpictures.com www.anatomy.tv).

use, with proportionally fewer grade 1 injuries and more grade 2 and grade 3 injuries ($p = 0.04$ [Kruskal–Wallis test], 4 degrees of freedom) (Table 3). No appreciable change in the frequency of severe injuries (Schaefer–Fuhrman grades 4 and 5) occurred, which suggests that the observed change in lower-grade injuries was attributable to upstaging of injuries following more comprehensive diagnostic evaluation and recognition of previously occult fractures.

In light of the increased diagnosis, we evaluated whether proportionally more injuries required intervention over time. Airway capture was used in 65% (58/89) of ELTIs overall, with endotracheal tube intubation being done as primary airway management in 52% (46/89). The use of endotracheal tube intubation versus conservative management essentially reversed over time ($p = 0.001$ [χ^2 test], 3 degrees of freedom). In spite of this tendency to resort to endotracheal tube airway capture more frequently, no significant change in operative management of ELTIs was observed over the same period ($p = 0.8$ [χ^2 test], 3 degrees of freedom) (Fig. 4). To better understand the rising tendency to establish a definitive airway, we determined the location of endotracheal tube placement: the

largest contributors to increased endotracheal tube placements were the emergency department and emergency medical services outside of hospital (Fig. 4).

For the 86 cases in which time from ELTI presentation to diagnosis was measurable, the median time to definitive diagnosis was brief (1.99 h), but a small number of very delayed diagnoses secondary to management of more pressing injuries caused positive skew (mean 14.5 h, 95% confidence interval [CI] 1.13–27.9 h). For the 46 cases that required operative intervention, the median time from presentation to procedure commencement was 1.87 hours (mean 12.2 h, 95% CI 4.54–19.9 h). Mean time to diagnosis reached by clinical methods was quicker than that

Fig. 2. Annual frequency of external laryngotracheal injuries and diagnostic modality that initially detected the injury.

Fig. 3. Proportion of external laryngotracheal injuries, by diagnostic era (2003 and earlier, and after 2003), according to diagnostic modality and need for interventional operative management (excluding purely endoscopic evaluation).

Table 3. Distribution of severity of external laryngotracheal injuries according to diagnostic era

Era	Schaefer–Fuhrman injury grade; no. (%) of patients n = 89					
	1	2	3	4	5	Total
2003 and earlier	9 (30)	12 (40)	3 (10)	4 (13)	2 (7)	30 (100)
After 2003	4 (7)	28 (47)	16 (27)	8 (14)	3 (5)	59 (100)

reached by diagnostic imaging, but not significantly so ($p = 0.8$ [χ^2 test], 3 degrees of freedom).

Changes in outcomes

We evaluated hospital LOS and survival over time secondary to the increasing tendency to establish a definitive airway. Fig. 5 shows mean LOS for the 27 patients in whom nonsevere ELTIs (Schaefer–Fuhrman grade ≤ 3) were diagnosed with no comorbid injuries, by diagnostic era. Length of stay was 2.3 (95% CI 0.14–4.8) days longer for the patients injured after 2003 than for those injured in 2003 or earlier, a nonsignificant difference ($p = 0.06$ [2-sample t test]). Again, a greater proportion of patients underwent intubation in the later cohort than in the earlier cohort. Survival did not change over time ($p = 0.2$ [χ^2 test], 3 degrees of freedom) ($n = 89$) and was not affected by the increased use of endotracheal tube intubation as primary airway management ($p = 0.08$ [χ^2 test], 3 degrees of freedom) ($n = 77$).

Fig. 4. Use and location of endotracheal tube intubation by diagnostic era. EMS = emergency medical services; ED = emergency department; ETT = endotracheal tube; OR = operating room.

Fig. 5. Box plots illustrating mean hospital length of stay according to diagnostic era for patients with nonsevere external laryngotracheal injuries. Error bars represent 95% confidence intervals (CIs), with data points outside 95% CI indicated by dots. Horizontal line represents mean value for each group.

DISCUSSION

Through the use of a large population-based data set, we identified significant change in the initial management of ELTIs, particularly increased endotracheal tube intubation, coincident with increasing incidence of these injuries. It is noteworthy that this increased reliance on endotracheal tube intubation was not accompanied by a corresponding increase in operative interventions. This suggests that ELTIs recognized in the era of highly sensitive CT technology do not necessarily need definitive airway capture and that conservative management with close observation in an experienced hospital setting is appropriate but underused. In our centre, patients who have undergone intubation are managed in the intensive care unit until extubation, which greatly increases cost during the hospital stay and likely prolongs LOS; however, this practice did not improve survival outcomes in the current study. We did not find a statistically significant increase in LOS among patients with isolated ELTI, despite a sizable difference in LOS between the early and late cohorts, but this may have been due to limited numbers. However, a decrease in LOS of 2 days is meaningful clinically. Interestingly, 5 of the 7 deaths in our data set occurred in patients who had undergone intubation. The other 2 patients had undergone cricothyroidotomy, which may reflect aggressive resuscitation in severely injured patients; 6 of the patients who died presented with comorbid injuries. Further investigation into cofactors and predictors of the increased use of intubation and increased LOS would be useful, but a study of rare events precludes multivariate analysis owing to insufficient data to draw accurate conclusions. In the era of increasing cost containment in medicine, the additional LOS associated with intubation is important given the increased costs related to intensive care unit admission versus ward admission and additional expenses related to mechanical ventilation versus airway observation.^{9,10}

Diagnostic imaging produced 2 direct effects on ELTI patterns: greater injury recognition and upstaging of injuries from those that may have been considered exclusively mucosal to contain small, nondisplaced fractures. It is not surprising that routine CT detects additional ELTIs, with enhanced details available on 2- and 3-dimensional views,¹¹ and CT has become an important part of ELTI evaluation.^{12,13} Still, it is critical to determine whether these injuries require additional management, particularly in the trauma setting, where a comorbid injury may be life threatening.¹⁴ Although to our knowledge the incidental injury conundrum has not been previously addressed for ELTIs, parallel issues exist for other injuries, such as adrenal, diaphragmatic, vertebral and vascular.^{15–18} Our data suggest that, although some identified injuries may not have been previously detected, this increase is not incidental since the surgical intervention rate remained stable. Nonetheless, ELTIs discovered by radiologic investigation as a result of the investigation protocol or targeted evaluation in cases in

which such an injury does not seem likely should be evaluated urgently given the potential for long-term sequelae if left unrepaired.^{3,4} Although it is tempting to attribute the greater use of endotracheal tube intubation to diagnostic imaging findings, in the current study, a large proportion of intubations were performed before diagnostic imaging by emergency department and emergency medical services personnel. Therefore, this increase more likely represents greater familiarity with endotracheal tube intubation techniques or less comfort in treating patients with signs of potential airway compromise. Although features detected on CT may provide some guidance, nonindicated early intubation is a significant issue in patients with ELTIs because it eliminates many of the clinical injury features that assist a surgeon in deciding to proceed with early operative intervention and, as a result, optimize both vocal and aerodigestive outcomes.^{19,20}

Fig. 6 shows a simplified algorithm applicable to the management of ELTIs in the trauma assessment. The primary need in laryngeal trauma, as in all trauma cases, is to establish an airway. In many instances of suspected laryngeal trauma, this is achieved by maintaining spontaneous respiration in a patient who can protect his or her airway until an otolaryngologist can examine the larynx via bedside flexible

endoscopy. A subset of these patients can be medically managed with favourable positioning, humidified supplemental oxygen, inhaled racemic epinephrine and systemic treatment with steroids. In cases in which the patient has a decreased level of consciousness, major multisystem trauma or impending airway compromise, an airway must be established through endotracheal intubation, awake tracheostomy or cricothyroidotomy. The use of intubation for management of ELTI is controversial, and multiple factors must be taken into account, including comorbid injuries, presence of experienced personnel and mechanism of injury.²² We caution against intubation in the setting of a known ELTI because of potential worsening of the injury, which can be minimized by performing an awake tracheostomy.^{1,13} Ideally, an otolaryngologist would be present during intubation to provide examination of the airway before tube placement via direct laryngoscopy, since an endotracheal tube makes examination of an injured larynx difficult. When necessary outside the operating room, an experienced physician should perform the intubation to avoid additional endolaryngeal trauma.²² In our study, the median time between presentation and commencement of an operative procedure (skin incision or endoscopy) was 1.87 hours, so we suggest that endotracheal tube intubation should be reserved for

Fig. 6. Initial management protocol for external laryngotracheal injuries (ELTIs). ATLS = Advanced Trauma Life Support; CT = computed tomography; ETT = endotracheal tube; ORIF = open reduction and internal fixation. Adapted from reference 21.

patients at risk for further decline in their medical condition in whom awake tracheostomy cannot be performed within 2 hours of presentation or would delay other treatment, such as a patient with uncontrolled hemorrhage or intracranial injury (Fig. 6). In such patients, cricothyroidotomy with a small tracheostomy tube or endotracheal tube may be less damaging to an injured larynx than oral or nasal intubation.

Limitations

Our study limitations relate to retrospective data collection, altered examination methods and operative philosophies over time, and the incorporation of a centralized database. Data gleaned from health records are prone to potential grading errors and inaccurate time reports, and they neglect decision-making processes incorporated by treating personnel. For example, reasons to obtain a definitive airway versus conservative management were not frequently recorded, and the clinical scenario for each case cannot be appreciated retrospectively. Grading errors may affect the observed change in injury distribution, and this may be further affected by a probable increase in lower-grade injuries more easily detected by current fibre-optic examination compared to prior endolaryngeal mirror examination. Furthermore, the accuracy of the data contained within the databases depends on extraction from health care provider records, which may be incomplete or illegible, so some injuries may not have been recorded and captured through our methodology. Finally, this study incorporated multiple hospital sites with a large number of emergency department physicians, trauma surgeons and otolaryngologists, who represent diverse practice patterns and familiarity with ELTI management. This limits our ability to compare our experience to that of other centres since it may not reflect practice profiles at different sites.

CONCLUSION

The use of endotracheal tube intubation in the early management of ELTIs increased significantly after the introduction of sensitive CT technology. Although prolonged hospital LOS was not significantly different between the pre-CT and post-CT cohorts in our series, this suggests that there is an increased need for intensive care unit stay and associated expense. Early recognition and appropriate management of these potentially life-threatening injuries remain paramount; however, increased discretion for airway intervention may improve overall care and permit earlier discharge, with decreased intensive care unit burden.

Acknowledgements: The authors thank Ms. Alma Rados with the University of Calgary Trauma Registry service and Ms. Anita Williams from Alberta Health Services for their assistance with database analysis and data retrieval.

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Competing interests: None declared.

Contributors: All authors designed the study. D. Randall acquired and analyzed the data, which L. Rudmik and C. Ball also analyzed. D. Randall and C. Ball wrote the article, which all authors reviewed and approved for publication.

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