Clinical Neuroradiology (2023) 33:1123–1131
https://doi.org/10.1007/s00062-023-01323-w

ORIGINAL ARTICLE

CT Findings in Laryngeal Trauma and the Clinical Implications

Gianna N. DiGrazia[1] · Serra L. Aktan[1] · Emma M. Sechrist[1] · Justina Rehn[1] · Cara Joyce[1] · Mariah H. Siddiqui[1]

Received: 28 September 2022 / Accepted: 30 May 2023 / Published online: 6 July 2023

Abstract

Purpose Acute traumatic osseous and cartilaginous injuries to the larynx are rare injuries presenting to the emergency department. Despite the low reported incidence, laryngeal trauma carries a high morbidity and mortality. The purpose of this study is to identify fracture and soft tissue injury patterns in laryngeal trauma and explore associations with patient demographics, mechanisms of injury, urgent airway and surgical intervention.

Methods A retrospective review of patients with laryngeal injury who underwent multidetector computed tomography (MDCT) imaging was performed. The CT findings of laryngeal and hyoid fracture location, fracture displacement, and soft tissue injuries were recorded. Clinical data including patient demographics, mechanisms of injury, frequency of airway and surgical intervention were also recorded. Correlation of imaging characteristics with patient demographics, mechanism of injury and interventions were assessed for statistical significance using χ^2 and Fisher's exact tests.

Results The median patient age was 40 years old with a strong male predominance. The most common mechanisms of injury included motor vehicle collisions and penetrating gunshot wounds. Thyroid cartilage fractures were the most common fracture type. Findings of fracture displacement and airway hematoma had a higher correlation with requiring urgent airway management.

Conclusion Radiologists' early recognition and prompt communication of laryngeal trauma to the clinical service is important to reduce associated morbidity and mortality. Displaced fractures and laryngeal hematomas should be promptly conveyed to the clinical service as they are associated with more complex injuries and higher rates of urgent airway management and surgical intervention.

Keywords Laryngeal fractures · Hyoid fractures · Neck trauma · Computed tomography · Laryngeal cartilage injury

Abbreviations

ENT	Otolaryngology
MDCT	Multidetector computed tomography
NSGY	Neurosurgery
PACS	Picture archiving and communication systems

Introduction

Acute laryngeal trauma, whether blunt or penetrating, is an uncommon occurrence within the emergency department. The well protected location of the larynx and underrecognition both clinically and radiographically limits the incidence to approximately 1 out of every 5000–30,000 emergency department visits [1–3]. Despite the low incidence, laryngeal trauma is associated with high morbidity and mortality [1, 3, 4]. Serious consequences of laryngeal trauma may be acute from airway asphyxiation, secondary to edema or hematoma formation, or chronic such as change in phonation, tracheal stenosis, and infection [3, 5]. Long-term consequences can often be prevented with prompt surgical intervention [4–6], highlighting the importance of early detection.

Clinical detection of laryngeal injury can be difficult as presenting symptoms vary vastly and do not always correlate with degree of internal injury [1, 4, 7]. Laryngoscopy is standard practice for suspected laryngeal trauma providing direct visualization of mucosal injury and real-time functional evaluation of vocal cord movement; however, visualization of injury extent by endoscopy may be difficult in the setting of massive airway edema. Multidetector computed tomography (MDCT) plays a crucial role in the trauma

✉ Gianna N. DiGrazia
gdigrazia99@gmail.com

[1] Department of Radiology, Loyola University Medical Center, 2160 S. 1st Avenue, Maywood, IL 60153, USA

setting allowing for rapid detection of laryngeal injuries minimizing the risk of airway compromise due to treatment delay. Radiologists interpreting these initial trauma examinations often have limited access to valuable clinical information, such as the mechanism of injury, severity, and clinical symptoms. Early and accurate assessment of subtle laryngeal trauma relies on a radiologist's consistent search pattern and understanding of laryngeal trauma injury patterns [4, 8–10].

Unfortunately, prior publications on imaging features in laryngeal trauma are often limited case series and case reports, likely due to its low incidence and/or underrecognition [3, 8]. Additional literature focuses on optimizing CT parameters and 2D and 3D reconstruction algorithms [4, 8, 11]. The purpose of this retrospective review was to identify the frequency of thyroid, cricoid and hyoid fractures, fracture displacement, airway edema and focal airway hematoma formation and to explore associations with patient demographics, mechanisms of injury, and urgent airway and surgical management strategies. Further investigation of laryngeal trauma imaging patterns with urgent management implications allows radiologists to recognize and communicate the potential for insidious clinical deterioration.

Methods

This retrospective study was approved by the Institutional Review Board and the requirement for informed consent was waived. Our institution is a university level 1 trauma center with a 24 h on call unit situated within a large metropolitan area. The inclusion criteria for the study were all adult trauma patients who underwent noncontrast or contrast-enhanced CT neck or cervical spine evaluation in the emergency department over a 17-year period from January 2003 through January 2020 with radiologically reported laryngeal injury.

Illuminate Insight (Softek, Overland Park, KS, USA), a radiology and pathology report search software, was utilized to identify patients through a keyword search including the following terms: "laryngeal fracture", "hyoid fracture", "thyroid cartilage fracture", "cricoid fracture", "laryngeal hematoma". The MDCT images were reviewed retrospectively on the picture archiving and communication system (PACS) imaging system by 3 senior radiology residents, with 3 years (G.D.), 3 years (E.S.) and 4 years (S.A.) of neuroradiology training, for hyoid, thyroid and cricoid fractures, amount of fracture displacement, airway edema, focal hematoma formation, cervical spine and vascular injuries. Reference was made to the original report provided by a board certified neuroradiologist, with a broad range in years of head and neck experience, and if findings were discrepant, the study was reinterpreted by a second board certified neuroradiologist with 5 years (M.B.) of subspecialized head and neck experience and a consensus decision was agreed upon. Data on patient demographics, trauma mechanism of injury, urgent airway management and surgical intervention were collected based on electronic medical record (EPIC) chart review. Reviewers were aware of the clinical information and mechanism of injury during the imaging interpretation. Exclusion criteria included examinations limited by motion artifacts or chronic laryngeal injuries.

Trauma mechanisms were defined as blunt or penetrating. Blunt trauma included motor vehicle accidents ($n = 12$), assault ($n = 7$), fall ($n = 3$), hanging/strangulation ($n = 3$), and struck by train ($n = 1$). Penetrating trauma included gunshot wounds ($n = 12$), a firework injury ($n = 1$), and a dog bite ($n = 1$). Urgent airway management was defined as requiring rapid intubation or tracheostomy prior to imaging or shortly following imaging interpretation. Surgical interventions included any case that was taken to the operating room for unstable injuries including laryngeal, cervical spine or vascular injuries.

MDCT Protocols

Because of the retrospective study design over 17 years and our tertiary care facility status, the MDCT protocols varied significantly between the cases. The protocols utilized are summarized in Table 1. The average slice thickness for these routine trauma protocols ranged anywhere from 1.25 to 5.0 mm. Coronal and sagittal reformats were produced. Additional reformats in nonstandard planes and/or 3-dimensional reconstructions were created at the PACS workstation as needed by the radiologists.

Diagnostic Interpretation Criteria

Fractures were diagnosed when a visible fracture line was present in ossified or non-ossified cartilages on at least 2 consecutive slices. The location and amount of displacement were recorded for each patient. Displacement was assessed by the distance between the fractured cortical margins, with any distance >1 mm considered displaced, as seen in Fig. 1a. Soft tissue abnormalities were also recorded including the presence of airway edema with non-focal hemorrhage or a focal hematoma. Suspected

Table 1 Multidetector CT protocols utilized

Protocol type	Number of studies
Cervical spine without contrast	8
Neck soft tissue without contrast	9
Maxillofacial without contrast	5
Neck angiogram with contrast	18

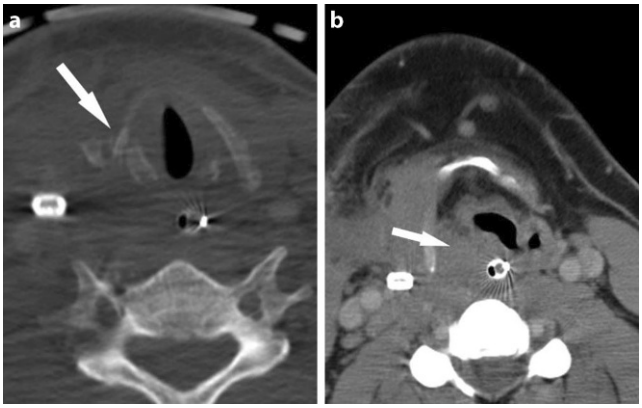

Fig. 1 20-year-old male status post gunshot wound. **a** Axial CT neck with a bone window at the level of the cricoid demonstrates a comminuted, displaced posterior right thyroid lamina fracture (*arrow*). **b** Axial CT of the neck with a soft tissue window at a slightly higher level demonstrates a hematoma (*arrow*) centered in the right pyriform sinus with medial displacement of the right aryepiglottic fold resulting in partial airway obstruction. This corresponded with direct laryngoscopy findings of an expanding hematoma in a difficult airway

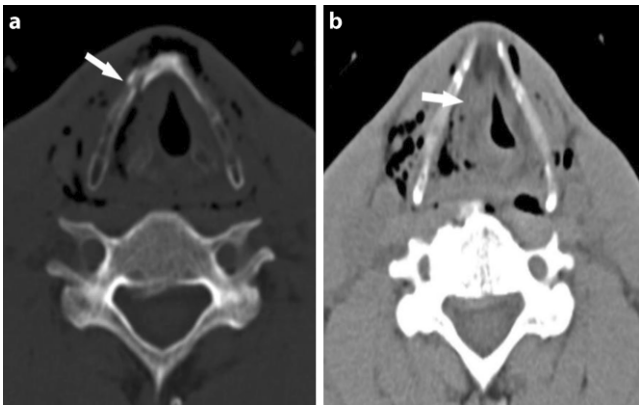

Fig. 2 48-year-old male status post fall. **a** Axial CTA of the neck with a bone window at the level of the false vocal cords demonstrates a minimally displaced, paramedian right thyroid lamina fracture (*arrow*). **b** Axial CTA of the neck with a soft tissue window at a slightly higher level demonstrates edematous changes of the right false vocal cord (*arrow*) with mild narrowing of the airway as well as air within the right false vocal cord. There is additional extralaryngeal air infiltrating the bilateral strap muscles and dissecting deep into the laryngeal mucosa into the retropharyngeal space

focal hematomas on imaging required evidence of a focal high attenuating (>35 HU) soft tissue mass, as seen in Figs. 1b, 2b, 3b. A confirmed hematoma was defined by those same MDCT criteria with confirmation by otolaryngology endoscopy or at the time of surgery. Associated injuries of the cervical spine and vasculature were also reported.

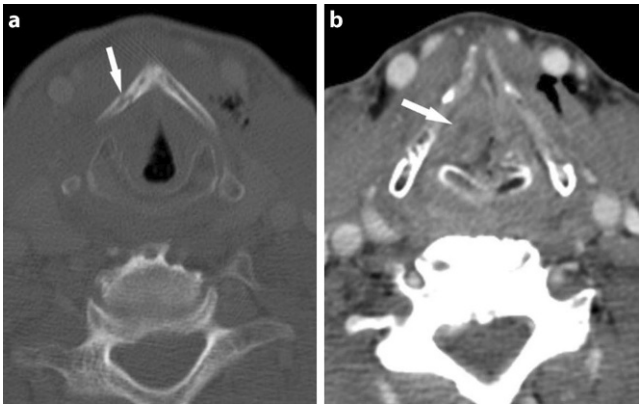

Fig. 3 60-year-old male status post assault. **a** Axial CT of the neck with a bone window at the level of the cricoid ring demonstrates nondisplaced right thyroid lamina fracture (*arrow*). **b** Axial CT of the neck with a soft tissue window demonstrates complete airway obstruction at the level of the glottis. Heterogeneously attenuating ovoid density of the right vocal cord (*arrow*) represents a 4 cm hematoma confirmed by direct laryngoscopy

Statistical Analysis

Patient and injury characteristics were summarized using descriptive statistics overall and stratified by injury type, fracture displacement, MDCT findings, and interventions. Univariable comparisons were performed using the χ^2-test, or Fisher's exact tests when expected cell sizes were small. A p-value <0.05 was considered significant in all analyses. Analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA).

Results

Incidence and Patient Demographics

In this study 40 cases of laryngeal trauma were identified through our Illuminate Insight keyword search which formed the basis of the current study. A search of our institution's trauma database estimated approximately 430,000 trauma encounters during this study's 17-year time frame, resulting in an incidence of laryngeal trauma of <1%.

A total of 48 fractures in 40 patients were identified (26 thyroid, 18 hyoid, 4 cricoid) in cases of external laryngeal trauma at our institution. Of the 40 patients, 87.5% were male ($n=35$) and 12.5% female ($n=5$) ranging in age from 20–76 years (mean 40 years, SD 16 years). The mechanisms of injury included gunshot wounds 30.0% ($n=12$), motor vehicle collisions 30.0% ($n=12$), assault 17.5% ($n=7$), fall 7.5% ($n=3$), hanging/strangulation 7.5% ($n=3$) and other 7.5% ($n=3$). Demographics and mechanism of injury incidence are summarized in Table 2.

Table 2 Patient characteristics

	Overall $N=40$	Blunt injury $N=26$	Penetrating injury $N=14$
Demographics			
Age (years)			
Mean (standard deviation)	40 (16)	41 (15)	37 (19)
Median (interquartile range) [range]	39 (48–49) [20–76]	41 (29–48) [20–75]	29 (23–50) [20–76]
Female, n (%)	5 (12.5)	4 (15.3)	1 (7.1)
Injury characteristics			
Mechanism of injury, n (%)			
Gunshot wound	12 (30.0)	0 (0.0)	12 (85.7)
Motor vehicle collision	12 (30.0)	12 (46.2)	0 (0.0)
Assault	7 (17.5)	7 (26.9)	0 (0.0)
Fall	3 (7.5)	3 (11.5)	0 (0.0)
Other	6 (15.0)	4 (15.4)	2 (14.3)
Fracture type, n (%)			
Cricoid only	1 (2.5)	1 (3.8)	0 (0.0)
Thyroid only	18 (45.0)	11 (42.3)	7 (50.0)
Hyoid only	13 (32.5)	6 (23.1)	7 (50.0)
Thyroid and cricoid	3 (7.5)	3 (11.5)	0 (0.0)
Thyroid and hyoid	5 (12.5)	5 (19.2)	0 (0.0)
Non-focal hemorrhage or a focal hematoma on imaging, n (%)	14 (35.0)	9 (34.6)	5 (35.7)
Cervical spine fracture, n (%)	9 (22.5)	5 (19.2)	4 (28.6)
Vascular injury, n (%) [n = 39]	4 (10.3)	1 (4.0)	3 (21.4)

Subjective and objective symptoms were not consistently documented for all cases as many patients presented intubated or tracheostomized. The most commonly reported subjective symptoms included anterior neck pain, dysphagia, odynophagia, weak/hoarse voice. The most commonly documented objective findings included anterior neck erythema, anterior neck laceration, edema, tenderness to palpation, crepitus, stridor, dysphonia.

The most common mechanisms of injury included gunshot wounds ($n=12$) and motor vehicle accidents ($n=12$), followed by assault ($n=7$). Additional data describing observed mechanisms of injury are summarized in Table 2.

Of the 40 cases, 10% ($n=4$) had associated vascular injuries, 22.5% ($n=9$) associated cervical spine fractures. Of the cases 61.5% ($n=24$) required urgent airway management including endotracheal intubation or tracheostomy for clinical instability in the setting of airway edema, airway hematoma, or other vascular or cervical spine injuries. Also, 38.5% cases ($n=15$) required intervention from otolaryngology (ENT) or neurosurgery (NSGY) including laryngeal fracture fixation, laryngoplasty and/or cervical spine fixation.

Fracture Location Assessment

The fracture patterns in the 40 cases included 45.0% ($n=18$) isolated thyroid cartilage fractures, 32.5% ($n=13$) isolated hyoid fractures, 12.5% ($n=5$) combination fractures of both the hyoid and thyroid, 7.5% ($n=3$) combination fractures of both the cricoid and thyroid and 2.5% ($n=1$) isolated cricoid fracture. Of the fractures 60% ($n=24$) were categorized on MDCT as displaced, 40% ($n=16$) nondisplaced fractures, 35% ($n=14$) cases had MDCT features of airway edema with non-focal hemorrhage or a focal hematoma. Of those 14, 36% ($n=5$) cases were confirmed a definite hematoma by laryngoscopy.

Fracture of the thyroid cartilage was the most common fracture type, as seen in Figs. 1a, 2a, 3a. Blunt trauma 73% ($n=19$) was the most common mechanism of injury of thyroid cartilage fractures compared to penetrating trauma 27% ($n=7$). Of thyroid fractures 69% ($n=18$) underwent urgent airway management and 35% ($n=9$) required otolaryngology or neurosurgery surgical intervention. Also, 31% ($n=8$) of thyroid fractures had imaging features of airway edema with non-focal hemorrhage or a focal hematoma, with 50% ($n=4$) confirmed hematomas on laryngoscopy.

Isolated hyoid fractures made up 32.5% ($n=13$) of cases, as seen in Fig. 4. The mechanism of injury was split nearly evenly between ($n=6$) blunt and ($n=7$) penetrating mechanisms. Of the cases 38.5% ($n=5$) had imaging features of airway edema with non-focal hemorrhage or a focal hematoma, with one confirmed hematoma on laryngoscopy.

Combination fractures involving both the thyroid and hyoid were 100% ($n=5$) due to blunt trauma. All combination fracture cases ($n=5$) required urgent airway management, 60% ($n=3$) had imaging features of airway edema with non-focal hemorrhage or a focal hematoma and 40% ($n=2$) had associated cervical spine injuries. Combination fractures involving both the thyroid and cricoid were 100% ($n=3$) due to blunt trauma. Of the three cases one had imaging features of airway edema with non-focal hemorrhage or a focal hematoma and required urgent airway management.

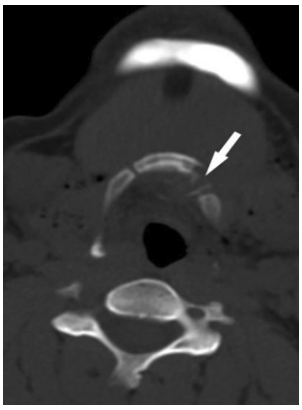

Fig. 4 28-year-old male status post gunshot wound. Axial CT of the neck demonstrates a comminuted fracture of the left hyoid bone (*arrow*)

No associated vascular or cervical spine injuries were noted in these combination thyroid and cricoid cases.

Fracture Displacement Assessment

Displaced fractures made up 60% ($n=24$) of the total fractures and of those 79% ($n=19$) required urgent airway management and 54% ($n=13$) underwent laryngoscopy. Of the cases 42% ($n=10$) had imaging features of airway edema with non-focal hemorrhage or a focal hematoma with 50% ($n=5$) of cases having a confirmed hematoma by laryngoscopy, as demonstrated in Fig. 1a, b. Of the displaced fractures 25% ($n=6$) had associated cervical spine fractures, 8% ($n=2$) associated vascular injury, and 42% ($n=10$) required neurosurgery or otolaryngology surgical intervention.

In the 5 cases of confirmed airway hematoma, 80% ($n=4$) had displacement >5 mm. Conversely all cases ($n=9$) with a displaced fracture >5 mm, required urgent airway management.

Nondisplaced fractures made up 40% ($n=16$) of the total fractures and of those 31% ($n=5$) required urgent airway management and 44% ($n=7$) underwent laryngoscopy. Of these fractures 25% ($n=4$) had imaging features of airway edema with non-focal hemorrhage or a focal hematoma with 0% of cases having a confirmed hematoma on laryngoscopy. Of the nondisplaced fractures, 19% ($n=3$) had associated cervical spine fractures, 13% ($n=2$) associated vascular injuries and 31% ($n=5$) required neurosurgery or otolaryngology surgical intervention.

The above percentages are summarized in Table 3 for comparison.

Table 3 Injury and treatment characteristics by fracture displacement

	Displaced fractures (in %), [$n=24$]	Nondisplaced fractures (in %), [$n=16$]
Incidence	60 (24/40)	40 (16/40)
Required urgent airway management	79 (19/24)	31 (5/16)
MDCT findings airway edema, with non-focal hemorrhage or a focal hematoma	42 (10/24)	25 (4/16)
Underwent laryngoscopy	54 (13/24)	44 (7/16)
Hematoma on laryngoscopy	21 (5/24)	0 (0/16)
Cervical spine fracture	25 (6/24)	19 (3/16)
Vascular injury	8 (2/24)	13 (2/16)
ENT/NSGY surgical intervention	42 (10/24)	31 (5/16)

ENT Otolaryngology, *NSGY* Neurosurgery, *MDCT* Multidetector Computed Tomography

Soft Tissue Abnormalities

Approximately 35% ($n=14$) of total cases had MDCT imaging features of airway edema with non-focal hemorrhage or a focal hematoma. In this group, 79% ($n=11$) required urgent airway management, 64% ($n=9$) underwent laryngoscopy by otolaryngology, and 34% ($n=5$) had a confirmed hematoma. Of the cases 71% ($n=10$) had displaced fractures, 29% ($n=4$) were nondisplaced, 43% ($n=6$) of cases had associated cervical spine fractures and 21% ($n=3$) had associated vascular injury and 43% ($n=6$) required neurosurgery or otolaryngology surgical intervention.

Of the total cases 65% ($n=26$) did not have MDCT imaging features of airway edema with non-focal hemorrhage or a focal hematoma. In this group, 50% ($n=13$) required urgent airway management, 42% ($n=11$) underwent laryngoscopy by otolaryngology and 0% ($n=0$) had a confirmed hematoma. Of the cases 54% ($n=14$) had displaced fractures, 46% ($n=12$) were nondisplaced, 12% ($n=3$) of cases had associated cervical spine fractures and 4% ($n=1$) had associated vascular injury, 35% ($n=9$) required neurosurgery or otolaryngology surgical intervention.

The above percentages are summarized in Table 4 for comparison.

Analysis for associations between patient demographics, mechanisms of injury, fracture type, fracture displacement, soft tissue injury and with urgent airway management and surgical intervention are summarized in Table 5. Of note, patients with displaced fractures were more likely to receive urgent airway management than those with non-displaced fractures (79.2% vs. 33.3%, $p=0.004$) but were not significantly more likely to receive ENT/NSGY interventions (41.7% vs. 33.3%, $p=0.60$). Rates of urgent airway management were higher among those with hematoma on imaging (84.6% vs. 50.0%, $p=0.04$). Those with cervical spine fractures were twice as likely to receive ENT/NSGY interventions (66.7% vs. 30.0%, $p=0.06$). Remaining associations in Table 5 did not show statistical significance.

Discussion

Laryngeal trauma is an uncommon occurrence in the emergency department. This study describes the relative frequency of patient demographics, mechanisms of injury, fracture types, fracture displacement, soft tissue injuries and analyzes the association with acute airway management and surgical intervention. Knowing which imaging features drive clinical outcomes is important as traumatic laryngeal injuries carry a morbidity rate of up to 37% and an estimated mortality rate of 13% [12, 13].

Table 4 Injury and treatment characteristics by presence or absence of airway edema with non-focal hemorrhage or a focal hematoma

	MDCT findings of airway edema with non-focal hemorrhage or a focal hematoma (in %), [$n = 14$]	Absent MDCT findings of airway edema with non-focal hemorrhage or a focal hematoma (in %), [$n = 26$]
Incidence	35 (14/40)	65 (26/40)
Required urgent airway management	79 (11/14)	46 (12/26)
Displaced fracture	71 (10/14)	54 (14/26)
Underwent laryngoscopy	64 (9/14)	42 (11/26)
Hematoma on laryngoscopy	36 (5/14)	0 (0/26)
Cervical spine fracture	43 (6/14)	12 (3/26)
Vascular injury	21 (3/14)	4 (1/26)
ENT/NSGY surgical intervention	43 (6/14)	35 (9/26)

ENT Otolaryngology, *NSGY* Neurosurgery, *MDCT* Multidetector Computed Tomography

The results of this single institution retrospective study are in agreement with previously published literature, including a higher prevalence of laryngeal fractures in men around age 40 years [1–3, 6, 10, 13–16]. This increased incidence in middle-aged men may be related to men having a higher degree of ossification of the cartilages compared to the population 18–25 years old [8, 9]. The laryngeal cartilages undergo ossification as part of the normal aging process, beginning around the ages of 18–20 years [17], and the more advanced the ossification process, the higher likelihood the cartilages will be fractured and detected by MDCT. Additionally, anatomic differences between men and women may explain the increased incidence considering the larger, more prominent size of the larynx in men [3].

The most common mechanisms of injury included gunshot wounds and motor vehicle accidents. High speed motor vehicle accidents, especially rear end collisions, tend to be a frequent cause of laryngeal trauma as demonstrated in prior studies [2–4, 8, 12]. The forward motion of the upper torso with neck hyperextension in deceleration injuries places the usually well protected larynx in a vulnerable position for injury. Penetrating trauma from gunshot wounds directed at the larynx is an obvious cause of injury.

The incidence of laryngeal trauma at our institution was approximately 1:11,000, which is comparable with prior reports between 5000–30,000 emergency department visits [1–4, 9, 13, 14]; however, these figures likely underestimate laryngeal trauma as it may go undetected for a variety of reasons. Clinically evident laryngeal trauma is uncommon, and it has been shown that laryngeal fractures are better recognized with dedicated thin slice examinations and 2D and 3D multiplanar reconstructions which may not be readily available in initial trauma imaging [8, 9]. In addition, the wide range of ossification of the laryngeal cartilages may make fractures difficult to detect [4, 9, 14].

Thyroid cartilage fracture was the most common type of laryngeal injury, similar to other reports including postmortem CT data [3, 9, 14–16, 18]. This was followed by hyoid fractures, and finally combination injuries involving the thyroid plus the hyoid or cricoid. There was only one incidence of an isolated cricoid fracture, which is similar to reports of cricoid fractures most commonly being associated with fractures of other cartilages [8]. Combination injuries involving multiple bony/cartilaginous structures were 100% of the time due to blunt trauma, usually motor vehicle accidents.

The MDCT findings associated with higher rates of urgent airway management and surgical intervention included displaced fractures and evidence of airway edema with non-focal hemorrhage or a focal hematoma. When comparing displaced fractures vs. nondisplaced fractures there was a higher percentage of patients requiring urgent airway management, higher incidence of airway hematomas, associated cervical spine injuries and surgical intervention within the displaced fracture group. This was even more so in cases with displacement >5 mm. In 80% cases with a confirmed hematoma by endoscopy, there was greater than 5 mm of displacement. Also, all cases with >5 mm of displacement required urgent airway management. Of note, most displaced fractures underwent open reduction and internal fixation of laryngeal fractures with mini-plates in an attempt to prevent long-term voice injury. Early surgery has been shown to decrease voice and airway complications by 40% [9, 19]. Therefore, recognizing and highlighting displacement can help the clinical service determine the necessity for operative reduction and fixation.

Laryngeal edema with non-focal hemorrhage or a focal hematoma is another important CT finding to recognize and report in a timely manner. If there is asymmetric soft tissue thickening or narrowing of the airway as demonstrated in Figs. 1b,2b, 3b, laryngeal edema must be reported and the images must be carefully inspected for a hematoma. In addition, careful evaluation of the vocal cords for thickening or bulging into the airway lumen can help raise suspicion for tearing of the vocal ligament or thyroarytenoid muscle. Highly attenuating lesions on unenhanced MDCT (>35 Hounsfield Units) within the airway can suggest an

Table 5 Factors associated with interventions

		Urgent airway management [$n=39$]		ENT/NSGY surgical intervention [$n=39$]	
Overall	40	24/39 (61.5%)		15/39 (38.5%)	
	N	*n* (%)	*p*-value	*n* (%)	*p*-value
Age (years)					
< 40	20	10 (50.0)	0.13	10 (50.0)	0.13
≥ 40	20	14 (73.7)		5 (26.3)	
Sex					
Female	5	3 (60.0)	0.99	2 (40.0)	0.99
Male	35	21 (61.8)		13 (38.2)	
Injury type					
Blunt	26	14 (56.0)	0.34	7 (28.0)	0.07
Penetrating	14	10 (71.4)		8 (57.1)	
Mechanism of injury					
Gunshot wound	12	8 (66.7)	0.02	6 (50.0)	0.28
Motor vehicle collision	12	9 (81.8)		6 (54.5)	
Assault	7	1 (14.3)		1 (14.3)	
Fall	3	1 (33.3)		0 (0.0)	
Other	6	5 (83.3)		2 (33.3)	
Fracture type					
Cricoid only	1	1 (100.0)	0.11	1 (100.0)	0.78
Thyroid only	18	12 (66.7)		7 (38.9)	
Hyoid only	13	5 (41.7)		5 (41.7)	
Thyroid and cricoid	3	1 (33.3)		1 (33.3)	
Thyroid and hyoid	5	5 (100.0)		1 (20.0)	
Thyroid displaced fracture					
Yes	12	11 (91.7)	0.03	5 (41.7)	0.68
No	14	7 (50.0)		4 (28.6)	
Hyoid displaced fracture					
Yes	11	8 (72.7)	0.16	5 (45.5)	0.33
No	7	2 (33.3)		1 (16.7)	
Any displaced fracture					
Yes	24	19 (79.2)	0.004	10 (41.7)	0.60
No	16	5 (33.3)		5 (33.3)	
Non-focal hemorrhage or a focal hematoma on imaging					
Yes	14	11 (84.6)	0.04	6 (46.2)	0.49
No	26	13 (50.0)		9 (34.6)	
Cervical spine fracture					
Yes	9	7 (77.8)	0.44	6 (66.7)	0.06
No	31	17 (56.7)		9 (30.0)	
Vascular injury [n = 39]					
Yes	4	3 (75.0)	0.99	3 (75.0)	0.28
No	35	21 (60.0)		12 (34.3)	

ENT Otolaryngology, *NSGY* Neurosurgery, *MDCT* Multidetector Computed Tomography

acute hematoma. Any evidence of edema or a hematoma need to be communicated promptly to the clinical service, as those patients with a focal hematoma have a higher frequency of urgent airway management, associated cervical spine and vascular injuries, and surgical intervention. Of the 14 cases that had findings for airway edema with non-focal hemorrhage or a focal hematoma, 5 hematomas were confirmed on endoscopy. Therefore, 36% of cases with suspicious MDCT findings had a confirmed hematoma. This percentage is likely an underestimate as three of the cases did not have a documented endoscopy and/or the report was not available in the medical records. In the group without MDCT findings of airway edema, there were no hematomas found on subsequent endoscopy highlighting the utilization

of MDCT in determining the need for follow-up endoscopy. Utilizing a 35HU threshold demonstrated a high sensitivity but low specificity for finding endoscopically confirmed hematomas. There may be value in utilizing and investigating a higher HU threshold above the normal neck soft tissues (20–40 HU) when reporting a focal hematoma. The HU thresholds of 45 or even 55 may improve specificity while still maintaining a high sensitivity; however, soft tissue injuries on postmortem CT studies compared with autopsy findings have demonstrated the shortcomings of CT in evaluating soft tissue hematomas [15, 16]. Magnetic resonance imaging is the best method for diagnosing soft tissue lesions in the neck but may not be readily available in the emergency setting [3, 8, 15, 16, 18]. The CT angiography of the neck may be the next best alternative to evaluate for osseous injury and contrast leakage into a soft tissue hematoma.

The limitations of our study included the retrospective design which utilized a variety of nondedicated MDCT trauma protocols and variable use of contrast to report on patterns of laryngeal trauma. Inevitably some of the injuries were likely undercharacterized; however, the question of whether further characterization is necessary and/or associated with improved clinical outcomes leaves room for further prospective investigation. Additional limitations included the retrospective design with inclusion criteria based on a keyword search in PACS. This may introduce selection bias based on only including correctly reported laryngeal fractures and inadvertently excluding patients with neck trauma without a radiologically defined fracture. False negative examinations in which laryngeal trauma was missed on initial interpretation were not sought given the extensive number of trauma studies. It was not feasible to review all trauma studies performed over a 17-year interval to identify laryngeal trauma that was potentially overlooked on imaging. This likely distorts the calculated prevalence and incidence of laryngeal trauma. Lastly, the study is limited by the small number of cases reviewed despite inclusion from a level 1 trauma center spanning a 17-year period. This is reflective of the relatively low incidence of laryngeal injuries. For further investigation, future multicenter investigations should be considered.

Conclusion

The detection and classification of laryngeal trauma is a multispecialty effort between emergency trauma physicians, otolaryngologists and radiologists. The MDCT is a first line examination in the acute trauma setting that plays a critical role in early detection and characterization of laryngeal injuries. The radiologists must understand their role in the evaluation of laryngeal trauma patients, including the benefits and limitations of MDCT imaging. Understanding the patterns of laryngeal injury and clinical implications is imperative to avoid overlooking a rare, yet insidious injury. Based on our review, cases with laryngeal fracture displacement or evidence of airway edema with a hematoma should be promptly conveyed to the clinical service as they are associated with more complex injuries and higher rates of urgent airway management and surgical intervention.

Declarations

Conflict of interest G.N. DiGrazia, S.L. Aktan, E.M. Sechrist, J. Rehn, C. Joyce and M.H. Siddiqui declare that they have no competing interests.

Ethical standards Ethical approval was waived by the local Ethics Committee of Loyola University Medical Center in view of the retrospective nature of the study and all the procedures being performed were part of the routine care. Informed consent was not obtained from all individual participants included in the study due to the retrospective design.

References

1. Schaefer SD. The acute management of external laryngeal trauma. A 27-year experience. Arch Otolaryngol Head Neck Surg. 1992; 118:598–604.
2. Bent JP, Silver JR, Porubsky ES. Acute laryngeal trauma: a review of 77 patients. Otolaryngol Head Neck Surg. 1993;109:441–9.
3. Buch K, Takumi K, Curtin HD, Sakai O. CT-based assessment of laryngeal fracture patterns and associated soft tissue abnormality. Eur Radiol. 2021; https://doi.org/10.1007/s00330-020-07548-4.
4. Shi J, Uyeda JW, Duran-Mendicuti A, et al. Multidetector CT of laryngeal injuries: principles of injury recognition. Radiographics. 2019;39(3):879–92.
5. Madani A, Pecorelli N, Razek T, Spicer J, Ferri LE, Mulder DS. Civilian airway trauma: a single-institution experience. World J Surg. 2016;40(11):2658–66. https://doi.org/10.1007/s00268-016-3588-9.
6. Schaefer SD. Management of acute blunt and penetrating external laryngeal trauma. Laryngoscope. 2014;124(1):233–44. https://doi.org/10.1002/lary.24068.
7. MacFarlane P, Stranz C, MacKay S. Missed laryngotracheal rupture leading to delayed presentation. ANZ J Surg. 2008;78:1030–1.
8. Becker M, Duboé PO, Platon A, et al. MDCT in the assessment of laryngeal trauma: value of 2D multiplanar and 3D reconstructions. Am J Roentgenol. 2013;201(4):W639–W47.
9. Becker M, Leuchter I, Platon A, et al. Imaging of laryngeal trauma. Eur J Radiol. 2014;83(1):142–54.
10. Schaefer SD. Use of CT scanning in the management of the acutely injured larynx. Otolaryngol Clin North Am. 1991;24:31–6.
11. Robinson S, Juutilainen M, Suomalainen A, Mäkitie AA. Multidetector row computed tomography of the injured larynx after trauma. Semin Ultrasound CT MR. 2009;30(3):188–94. https://doi.org/10.1053/j.sult.2009.02.002.
12. Lee WT, Eliashar R, Eliachar I. Acute external laryngotracheal trauma: diagnosis and management. Ear Nose Throat J. 2006;85(3): 179–84.
13. Jewett BS, Shockley WW, Rutledge R. External laryngeal trauma analysis of 392 patients. Arch Otolaryngol Head Neck Surg. 1999;125:877–80.

14. Wang AA, Feng AL, Rao V, Naunheim MR, Juliano AF, Song PC. Clinical, radiologic, and endolaryngeal findings in laryngeal fractures: a 15-year case series. OTO Open. 2022;6(1):2473974X22108 0164.
15. Treitl KM, Aigner LI, Gazov E, et al. Injuries of the isolated larynx-hyoid complex in post-mortem computed tomography (PMCT) and post-mortem fine preparation (PMFP)—a comparison of 54 forensic cases. Eur Radiol. 2020;30(8):4564–72. https://doi.org/10.1007/s00330-020-06770-4.
16. Kempter M, Ross S, Spendlove D, et al. Post-mortem imaging of laryngohyoid fractures in strangulation incidents: first results. Leg Med. 2009;11(6):267–71. https://doi.org/10.1016/j.legalmed.2009.07.005.
17. Castelijns JA, Becker M, Hermans R. Impact of cartilage invasion on treatment and prognosis of laryngeal cancer. Eur Radiol. 1996;6:156–69.
18. Schulze K, Ebert LC, Ruder TD, et al. The gas bubble sign-a reliable indicator of laryngeal fractures in hanging on post-mortem CT. Br J Radiol. 2018;91(1084):20170479. https://doi.org/10.1259/bjr.20170479.
19. Mendelsohn AH, Sidell DR, Berke GS, John MS. Optimal timing of surgical intervention following adult laryngeal trauma. Laryngoscope. 2011;121(10):2122–7. https://doi.org/10.1002/lary.22163.

Further Reading

20. Eaton DK, Kann L, Kinchen S, et al. Youth risk behavior surveillance—United States, 2011. MMWR Surveill Summ. 2012;61(4):1–162.
21. Fuhrman GM, Stieg FH 3rd, Buerk CA. Blunt laryngeal trauma: classification and management protocol. J Trauma. 1990;30:87–92.
22. Randall DR, Rudmik LR, Ball CG, Bosch JD. External laryngotracheal trauma: incidence, airway control, and outcomes in a large Canadian center. Laryngoscope. 2014;124(4):E123–E33. https://doi.org/10.1002/lary.24432.