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Musculoskeletal, airway, and vascular injuries in the patient with nonjudicial hanging: A narrative review for the emergency clinician

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Abstract:

Non-judicial hanging events presenting to emergency healthcare providers exhibit a wide range of severity, from cardiac arrest to minor soft tissue neck contusions, making it essential for providers to anticipate potential injuries. This review investigated the frequency of musculoskeletal, neurologic, airway, and vascular injuries to neck structures following such events. A narrative review of the PubMed database was conducted, selecting hypothesis-testing articles based on criteria including non-judicial hanging, emergency department evaluation, and consideration of at least one of the four injury areas. Two reviewers selected the final articles, analyzed the data, and investigated three questions focusing on the frequency of these injury types. The reference lists of the selected articles were also reviewed for additional relevant studies. The analysis included 30 articles (3809 patients) for musculoskeletal and neurologic injuries, 20 articles (2047 patients) for airway injuries, and 13 articles (2717 patients) for vascular injuries. The overall injury rates in the neck region among the study population were musculoskeletal 3.0%, neurologic 0.5%, airway 5.2%, and vascular 2.5%. In conclusion, among patients surviving to emergency department arrival after a non-judicial hanging event, the rates of injury to neck structures are low, with airway injuries being the most frequent at approximately 5% of cases. Injuries were observed to be more common in adults compared to pediatric patients, and the medical significance of these injuries varied considerably. Further research is necessary to more comprehensively define the expected pathologies associated with this patient presentation and to guide the most appropriate evaluation strategies.

Keywords:

Airway injury, hanging, intentional, musculoskeletal injury, nonjudicial, vascular injury

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Introduction

A hanging event is defined as occurring when external forces via a rope or other constructing device are applied to the neck, involving partial or complete suspension of the body.[1] Hanging events are separated into judicial and nonjudicial mechanisms. Judicial hanging is a method of execution used by governmental agencies, characterized by a specific protocol that uses mandated rope and knot configurations, resulting in a calculated free fall with the resultant suspension of the person. This process is designed to cause rapid death via sudden hyperextension of the neck, which produces bilateral pedicle fractures of the second cervical vertebra and associated laceration of the high cervical spinal cord.[2,3]

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Nonjudicial hanging describes a hanging event that does not include the specific required features of a judicial hanging; it can occur in the setting of intentional self-harm (i.e., suicide attempt), a malicious attempt to kill someone (attempted murder), or accidentally due to a range of scenarios. As such, the various mechanisms of nonjudicial hanging do not allow a concise definition other than that of an event in which a rope or other constructing device is applied in the neck while the person is either in partially or completely suspended. And, due to the varied mechanisms of nonjudicial hanging, a broad spectrum of injuries can be encountered in the victim, ranging from minimal contusions to the soft tissues of the neck to cervical spine fracture or dislocation, airway compromise, and vascular injury. While a nonjudicial hanging event results in rapid death due to compression of airway and vascular structures, a near-hanging event does not necessarily produce immediate death due to the suspended constriction of the neck.

The emergency clinician will encounter these patients across a broad spectrum of severity. Approximately half of nonjudicial hanging victims who are transported to the emergency department (ED) will experience cardiac arrest, with related significant morbidity and mortality, and will either be endotracheally intubated prior to ED arrival or require this intervention soon after arrival in the emergency department.[4] The remainder of these patients will arrive in the ED with potential injuries that can range from benign superficial soft-tissue damage to potentially life-threatening injury to the neurologic, musculoskeletal, airway, and vascular structures of the neck. Reported injuries include cervical fractures and/or dislocations, cervical spine ligamentous disruptions, spinal cord contusions and lacerations, spinal nerve root injuries, tracheal occlusions, laryngotracheal fractures and disruptions, arterial and venous occlusions, arterial dissections and pseudo-aneurysms.[3-6] This list of injuries only focuses on structures in the neck and does not include the various central nervous system sequelae such as subarachnoid hemorrhage, hypoxic brain injury, and other postcardiac arrest syndrome issues, which also require careful assessment in the emergency department.

An understanding of the possible injuries and their likelihood of occurrence is crucial to the emergency clinician in these often-critical situations, as it informs timely diagnosis and intervention. Thus, we undertook this narrative review.

Methods

Literature search and article inclusion

A literature search was conducted with the assistance of a medical librarian using the PubMed database from the date of its inception until November 15th, 2023. Randomized controlled trials (RCTs) and nonrandomized studies (nonrandomized controlled trials, interrupted time series, controlled before-and-after studies, cohort studies, and case–control studies) were eligible for inclusion. Unpublished studies (e.g., conference abstracts, trial protocols), animal studies, and case reports were excluded; beyond article type, inclusion criteria for article selection also included studies published in the English language. Considering clinical information and article selection, appropriate articles were included for initial review if all of the following predetermined criteria were met: (1) nonjudicial hanging event; (2) evaluation and management in the ED; and (3) study focus on at least one area of neck region injury (musculoskeletal injury, airway injury, or vascular injury).

A literature search was conducted using the PubMed database to identify studies involving patients presenting to the ED after a nonjudicial hanging event, with consideration of musculoskeletal/neurologic, airway, and vascular injuries. Search terms included ("near hanging" OR "near-hanging" OR ["hanging" AND "suicide"]), ("ed" OR "emergency department" OR "trauma center" OR "trauma centre" OR "trauma workup" OR "admitted"), and ("c-spine" OR "cervical spine" OR "spine" OR "fracture" OR "airway" OR "cervical" OR "injury" OR "vascular" OR "carotid"). The results from all three searches were combined using an "and" methodology to produce the initial article set. The search was conducted on November 15th, 2023. PubMed filters applied to the search included the exclusion of case reports and review articles.

Article selection process

Studies were identified for initial review based upon consideration of the title and abstract; in cases in which there was uncertainty as to whether the study would meet inclusion criteria as described above, the full text was reviewed. An initial review of the identified articles was performed by a single investigator (BS). Studies initially selected for inclusion were then reviewed by a second investigator (WB). Only studies deemed appropriate for inclusion by both investigators were included in further analysis. In addition, the reference lists of the initially selected articles were reviewed for any further inclusions into the study. If any such reference met the article type and clinical inclusion criteria, then they were included in the ultimate article set for review and analysis. A flow diagram depicting the article review, exclusion, and selection process is depicted in Figure 1. Once selected, articles were then placed into one or more of three categories based on their individual topic focus: Musculoskeletal/neurologic injury, airway injury, or vascular injury. This classification was

necessary due to the three separate injury types that were under consideration.

Results

Study selection

A total of 139 unique articles were identified. Thirty-eight articles were identified via title/abstract review for additional consideration, leaving 32 articles selected for further full-text review; from this group, 25 articles were selected for inclusion. An additional five articles were chosen from the reference lists of the selected articles, resulting in 30 articles for final inclusion and study analysis.[4,7-35] Refer to Figure 2 for a flow diagram depicting the article review, exclusion, and selection process, resulting in the articles for review and analysis; Table 1 shows the list of selected articles.

Study characteristics

Once selected, these articles were placed into one or more of three injury categories based on their individual topic focus: musculoskeletal/neurologic injury, airway injury, or vascular injury. Of the selected articles, all 30 (including 3809 patients) considered musculoskeletal and neurologic injury, 20 articles (including 2047 patients) considered airway injury, and 13 articles (including 2717 patients) considered vascular injury. Several articles had more than one focus, i.e., consideration of more than one injury category, including Bordia *et al*., which considered all three types of injuries. Salvetti *et al*.[33] examined a subset of the data that was also analyzed in de Charentenay *et al*.,[4] and as a result, the Salvetti study[33] was excluded from cumulative data counts when both studies were considered together.

Results and synthesis of individual studies

We were able to extract data from all 30 studies;[7-35] the overall rates of injury were noted as follows: musculoskeletal 3.0%, neurologic 0.5%, airway 5.2%, and vascular 2.5%. Table 1 and Figures 3-5 shows additional data from the selected studies.[7-35]

General Discussion

In performing our article review and data extraction, we were primarily interested in exploring three important areas of injury involving the spine (including both musculoskeletal elements, the spinal cord, and nerve roots), the airway, and vascular structures in the neck. We specifically addressed three questions, including the following:

1. In patients presenting to the hospital after nonjudicial hanging, what is the rate of musculoskeletal and/or neurologic (spinal cord or nerve root) injury?
2. In patients presenting to the hospital after nonjudicial hanging, what is the rate of airway injury?
3. In patients presenting to the hospital after nonjudicial hanging, what is the rate of vascular injury?

We will explore answers to these three questions, followed by a general discussion of our results related to musculoskeletal/neurologic, airway, or vascular injuries in the nonjudicial hanging ED patients.

In patients presenting to the hospital after nonjudicial hanging, what is the rate of musculoskeletal and/or neurologic (spinal cord or nerve root) injury?

In our analysis of 3809 patients following nonjudicial hanging in all 30 included articles, we observed a relatively low number of bony or ligamentous spinal injuries in 115 (3.0%) patients; Figure 3 shows a description of musculoskeletal and spinal cord injury occurrences. Although there were limitations in data reporting across studies, the available evidence suggests that the majority of these injuries manifested as cervical spine fractures, with additional occurrences of ligamentous injuries, vertebral subluxations and dislocations, as well as thoracic spine fractures. Cord and nerve root injuries were studied in 10 articles, with a total of 8 injuries (0.5%) found among 1530 patients. These included three cord contusions, one cord laceration, and four cervical disc injuries.

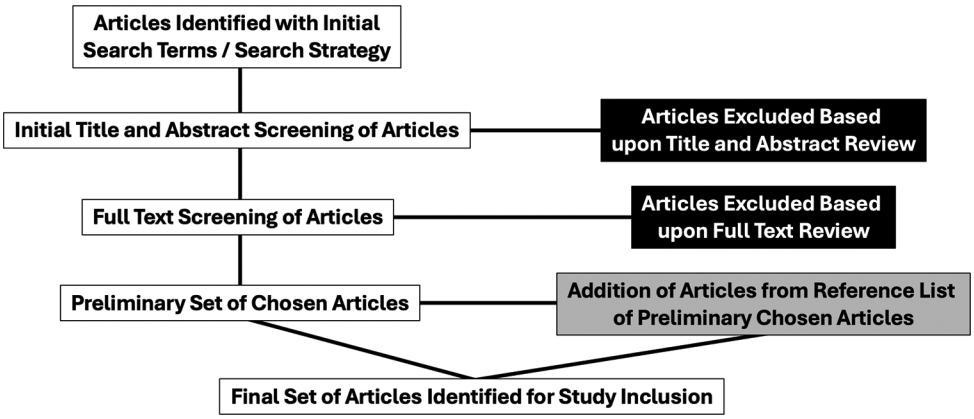

Figure 1: Methodology of article selection

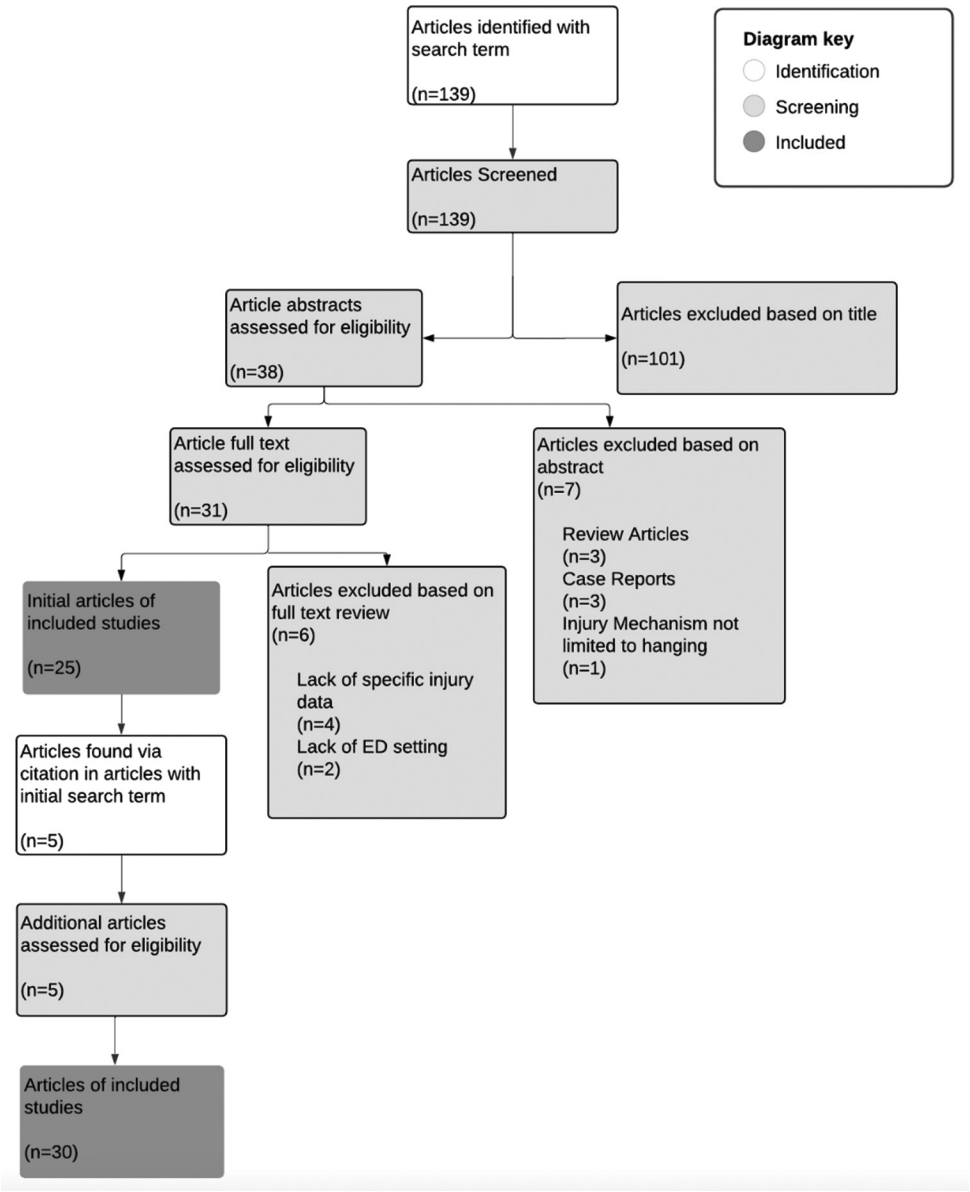

Figure 2: Observed process of article selection

The pediatric subset, consisting of 319 cases across the four articles that focused on pediatric patients, demonstrated interesting patterns. Two questionable ligamentous injuries and two atlanto-occipital dislocations were reported on imaging, yet there were neither vertebral fractures nor cord or nerve root injuries identified, resulting in a rate of musculoskeletal injury of 1.3%.

Two articles specifically focused on patients who had experienced cardiac arrest, and one article included patients with either cardiac arrest or coma. These were combined into a single subset containing 743 cases. The rate of bony or ligamentous spinal injuries in this group was 2.7% despite their greater complexity and severity, as evidenced by a mortality rate of 59.9% compared to 26.1% in the overall study population. It should be noted that mortality most often resulted from hypoxic brain injury and other sequelae related to the initial asphyxial event.

Among the entire group of patients, presentations varied widely. About 32.2% of cases presented in cardiac arrest or had received cardiopulmonary resuscitation and 40.0% were intubated either prior to arrival to the hospital or while being treated in the ED, in the articles that reported these metrics. Many articles also reported their median Glasgow Coma Scale (GCS) score on arrival, ranging from scores of 3–14. Several studies, including Bordia *et al*.[8] and Subramanian *et al*.,[16] attempted to stratify patients into groups depending on GCS and found no statistically significant difference between GCS 15 and

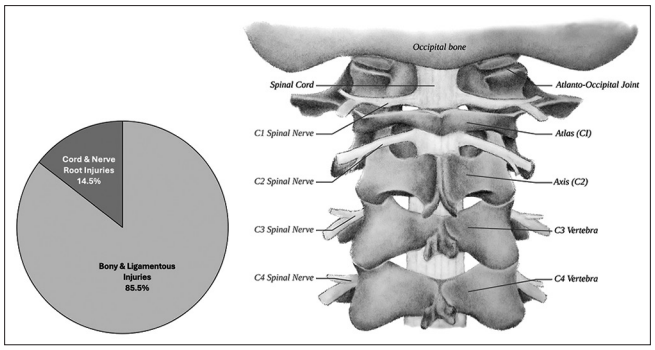

Figure 3: (Left) Summary of musculoskeletal and neurologic injury types. (Right) Anatomic depiction of injury locations for musculoskeletal and neurologic injuries

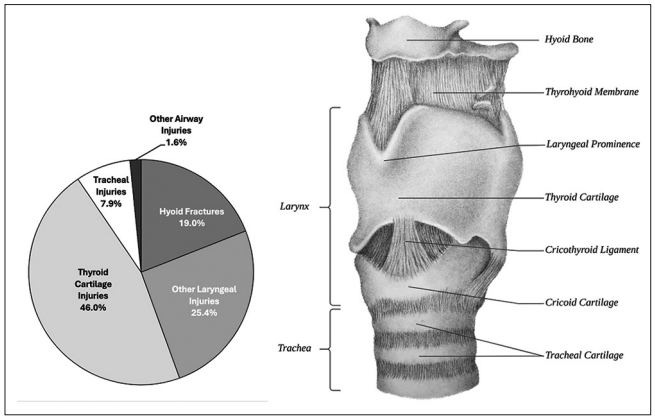

Figure 4: (Left) Summary of airway injury types. (Right) Anatomic depiction of injury locations for airway injuries

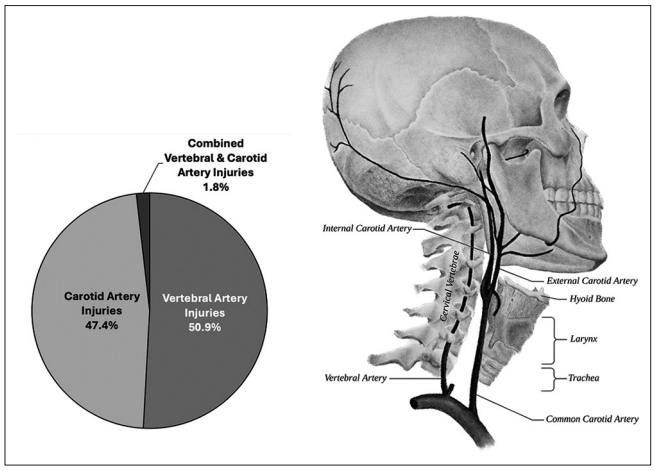

Figure 5: (Left) Summary of vascular injury types. (Right) Anatomic depiction of injury locations for vascular injuries

GCS <15 for abnormalities affecting the musculoskeletal spine and spinal cord; this is consistent with our finding that patients who were either comatose or in cardiac arrest did not have higher rates of bony or ligamentous spinal injuries– 2.7% versus 3.0% in all patients combined.

Imaging methods and frequency varied notably across articles. While some required imaging for inclusion, most also included patients whose cervical spine injuries were ruled out through physical examination. About 17.3% of patients did not receive any imaging during their workup in the nine articles where this information was available. Plain-film radiography (i.e., X-rays) tended to be the primary imaging modality in older articles, while computed tomography (CT) was more common in the more recent articles. Because of these differences in evaluation, nerve root, spinal cord, and ligamentous injuries may be underreported in comparison to bony injuries.

In patients presenting to the hospital after nonjudicial hanging, what is the rate of airway injury?

As compared to musculoskeletal and spinal cord injury, we found a higher rate of injury to the airway of 5.2% (106 patients) in our analysis of 2047 individuals following nonjudicial hanging in the 20 articles. Among 106 patients with airway injuries, a total of 126 distinct injuries were documented. Of these injuries, 46.0% were characterized as thyroid cartilage injuries, 19.0% were hyoid bone fractures, and 7.9% were categorized as tracheal injuries. An additional 25.4% were broadly termed laryngeal injuries, which may have included injury to the thyroid cartilage or hyoid bone. 1.6% were other airway injuries, comprising one complete laryngotracheal separation and one pharyngeal tear. Thyroid cartilage injuries were primarily fractures, with one instance of thyroid cartilage dislocation. Laryngeal injuries were predominantly cartilage fractures, though laryngeal edema and laceration were rarely noted. Tracheal injuries were minimally described in the articles. Figure 4 shows a summary of airway injury types.

In the pediatric subset containing 194 cases in which airway injuries were investigated, only a single hyoid fracture was found, yielding an airway injury rate of just 0.5% in pediatric nonjudicial hangings. This rate further supports the trend of decreased injury rates observed in pediatric victims of nonjudicial hanging as compared to adults. The limited occurrence of hyoid fractures in this subset could suggest a relatively lower vulnerability of the pediatric airway to injury in such circumstances, further emphasizing the distinctive patterns of injury between pediatric and adult populations in nonjudicial hanging cases.

In patients presenting to the hospital after nonjudicial hanging, what is the rate of vascular injuries?

We found the rate of cervical (i.e., located in the neck) vascular injury to be 2.5% in the subset of 2717 patients in the 13 articles where such injuries were categorized. Vascular injuries were primarily arterial dissections,

Table 1: Summary of publications selected for inclusion in analysis with key data[8-36]

Subgroup	Paper	Patient Number (*n*)	Age (years) *median (IQR) }or mean (±SD)	Gender (% male)	GCS *median (IQR) or mean (±SD)	Mortality (%)	Musculoskeletal +/- Neurologic Injuries (*n*)	Airway Injuries *n*)	Vascular Injuries (*n*)
General	Hopkins *et al.*	124	29*	53%	–	13.8%	–	5	3
	Bordia *et al.*	738	33*	72.9%	–	30.9%	46	50	44
	Ribaute *et al.*	162	38.5**	77.2%	–	21.0%	1	26	4
	Lee *et al.*	70	44.3**	47.1%	–	–	2	–	–
	de Charentenay *et al.*	886	43*	79.6%	3*	43.9%	32	–	8
	Buitendag *et al.*	154	29.4**	84.4%	–	2.5%	10	2	–
	Betz *et al.*	98	30**	75.5%	7*	19.4%	3	3	2
	Schoberg *et al.*	78	34**	86%	14*	8.0%	0	1	0
	Kao and Hsu	41	55.5**	56.1%	–	41.5%	0	0	–
	Jawaid *et al.*	101	–	71.2%	–	5.9%	3	–	–
	Subrammanian *et al.*	125	31.2**	77.6%	–	8.0%	1	1	2
	Aydin *et al.*	22	33*	68.2%	14*	13.6%	3	–	–
	Atreya and Kanchan	10	28.8**	50%	9.8**	0%	–	–	–
	Solbi *et al.*	43	24.2**	100%	6*	9.3%	2	–	–
	Wee *et al.*	21	46.5**	42.9%	7*	0%	0	–	1
	Nichols *et al.*	67	29.6**	91%	8.1**	14.9%	3	4	2
	Salim *et al.*	63	28**	87.3%	–	9.5%	3	4	1
	Boots *et al.*	161	28*	82%	13*	16.0%	4	8	1
	Hanna	13	31**	92.3%	9.9**	0%	0	–	–
	Davidson	72	–	68%	–	6.0%	0	–	–
	Penney *et al.*	42	–	90%	14*	12.0%	2	1	–
	Aufderheide *et al.*	67	28**	69%	–	35.8%	0	–	–
	Krol and Wolfe	39	23.2**	90%	–	7.7%	0	–	–
Pediatric	Svendiman *et al.*	128	11.3**	60.9%	11*	32.0%	2	1	0
	Kline-Fath *et al.*	66	13*	59%	–	12.0%	2	0	0
	La Count *et al.*	84	11.5*	64.3%	10*	22.6%	0	–	–
	Davies *et al.*	41	13.2**	68%	–	39.0%	0	–	–
Cardiac Arrest +/- Coma Presentation	Salvetti *et al.*	450	43*	77.7%	3*	82.0%	17	–	–
	Kim *et al.*	280	39.5**	51.4%	–	25.4%	2	–	–
	Wee *et al.*	13	38.5**	30.8%	–	38.5%	1	–	–

affecting both anterior (internal, external, and common carotid arteries) and posterior (vertebral artery) circulation vessels. Other vascular injuries included various arterial occlusions and pseudo-aneurysms. Rates of injury occurred at approximately equal frequencies in both the vertebral and carotid arteries. Figure 5 shows a summary of vascular injury types.

The diagnostic evaluation which identified vascular injuries varied across the 13 studies, including conventional angiography, CT angiography (CT-A), magnetic resonance angiography (MRA), and Doppler ultrasound. The aggregate diagnostic yield of any form of vascular imaging was 6.3% in the 10 articles that frequency of imaging modalities was specified. Among these articles, vascular imaging was only obtained in 55.4% of cases, suggesting that this relatively high rate of yield may be due to vascular imaging being reserved for more severe cases or those with specific concerning or suggestive clinical features. Ribaute *et al*. observed that nearly all patients in their sample with cervical vascular injuries had a GCS score <8, and all of them required endotracheal intubation with assisted mechanical ventilation during their initial treatment. Other articles, however, found cervical vascular injuries to be present in a subset of patients with a GCS of 15.[15,20] Despite a normal GCS, these cases generally involved suggestive or concerning signs or symptoms during the ED and subsequent evaluations.

It must be noted that the actual number of cervical vascular injuries remains unknown in that nearly half (44.6%) of this patient subset did not undergo vascular imaging.

There were no observed cervical vascular injuries among 194 pediatric patients, 114 of whom received vascular imaging. This further emphasizes the decreased injury risk of pediatric hanging victims.

Discussion

In our narrative review of nonjudicial hanging events, we noted the occurrence of a range of injuries to the patient in general and the structures of the neck in particular. First of all, the rate of cardiac arrest and/or unresponsiveness was quite high, with associated significant mortality rate of approximately 60%, a rate which was more than twice the overall frequency of deaths in those presenting for nonjudicial hanging. It is notable that approximately one-third of the patient group experienced cardiac arrest and close to half of these patients had undergone endotracheal intubation prior to ED arrival or soon after emergency department care was initiated. Of course, the ED evaluation of these ill patients was likely impacted by their presentation, meaning that injuries may not have been noted in a portion of these individuals if they did not survive the ED visit or early critical care admission. Interestingly, the rate of injury to the cervical spine in this group was 2.7%.

When considering the rate of documented injury to structures in the neck, we found that the rate of injury was low, in all patients musculoskeletal 3.0%, neurologic 0.5% (i.e., spinal cord or nerve roots), airway 5.2%, and vascular 2.5%.; and in pediatric patients, musculoskeletal 1.3%, neurologic (i.e., spinal cord or nerve roots) 0, airway 0.5%, and vascular 0. Airway injury was noted most frequently, yet still at a low rate, in 5.2%; airway injury was not found in the pediatric study population. We noted the least frequent occurrence of injury to the spine cord or nerve roots, which occurred in 0.5% of the adult study population and did not occur in the pediatric patient group.

Several interesting themes are noted regarding the rates of observed injury. It is notable that the overall rates of injury were low; while the cause(s) of these low rates is not known, it likely results from the range of mechanisms and scenarios in which nonjudicial hanging can occur, some of which approaches the dangerous features of judicial hanging while others are much less concerning mechanistically. Further, we were not able to explore the clinical significance nor the impact of the noted injuries. Certainly, the uncommon cases of vertebral dislocation, laryngotracheal separation, and vertebral artery dissection likely represented significant injuries, while ligamentous injury without subluxation or dislocation and smaller hyoid bone fractures did not impact clinical care nor the patient's outcome. Finally, these injury rates represent patients who survived the ED and were clinically stable for advanced diagnostic evaluation in the emergency department. Patients who expired in the prehospital setting and those individuals who survived ED arrival yet were unstable and then died were not considered; there is a very high likelihood that these patients likely had higher rates of injury to bony, airway, and vascular neck structures.

In general, the pediatric population experienced significantly lower rates of injury in all four categories that we considered. Among the 319 pediatric cases, no cervical spine fractures were observed; as expected, imaging findings rarely impacted clinical management in these patients. This trend is attributed to the lower kinetic energy involved in pediatric hangings (i.e., the distance of the suspended fall and the overall smaller body mass) coupled with the heightened vulnerability to suffocation due to anatomical differences, such as underdeveloped laryngeal cartilages.[36] Our data do not allow us to make all-encompassing recommendations regarding the consideration of musculoskeletal, neurologic, airway and/or vascular injury in certain pediatric patients, yet it

does suggest the selective application of imaging studies is likely appropriate.

Imaging varied considerably across the study population from the 30 selected articles. For example, when evaluating for possible musculoskeletal or neurologic injuries; some studies employed CT and/or magnetic resonance imaging (MRI) while others used the clinical evaluation, including the focused history and physical examination. Furthermore, remote (i.e., older) studies also employed plain-film radiography as the only imaging study when considering musculoskeletal injuries, while more recent studies relied almost exclusively on CT imaging. In fact, in the nine studies where imaging frequency was reported, 17% did not undergo imaging of any sort in the evaluation of musculoskeletal or neurologic injury; clinicians relied on the clinical assessment to rule out significant injury to neck structures. Considering the vascular injury subset of patients, only 55.6% of patients underwent vascular imaging of any type, including CT-angiography, magnetic resonance angiography, or duplex ultrasonography.

Recently, some authors from the selected studies have argued for less imaging during the evaluation of the patient with nonjudicial hanging, proposing that such extensive evaluations lead to increased cost, radiation exposure, and false positive results that can complicate treatment.[8,12,16] Of the many variables which impact the decision to image as well as the choice of imaging strategies, several obvious clinical features include the presenting mental status and observed clinical abnormality (neurologic deficit, airway compromise, etc.). For example, an unresponsive patient is unable to provide an adequate history or cooperate with a meaningful physical examination, thus imaging is highly likely to occur. Similarly, a patient with noted neurologic deficit or obvious respiratory compromise will almost certainly undergo imaging as treatment progresses. Notably, Subramanian *et al*.[16] found that in patients with GCS 15, the absence of cervical spine tenderness, or concerning signs or symptoms on physical examination had a 100% negative predictive value for the presence of significant neck injury; further, Hopkins *et al*.[7] documented similar findings, noting that all patients with normal GCS and normal physical examinations had unremarkable cervical spine imaging.

Limitations

Our study had several limitations. Most importantly, it and its component studies from the selected articles are retrospective in nature; retrospective studies use data that was not collected in a formatted consistent fashion in a real-time scenario. Second, three articles involved strangulation injuries in their inclusion criteria without distinguishing them from hanging injuries, all involving pediatric patients. This inclusion may have contributed to falsely low rates of spinal and airway injuries that we observed in the pediatric population, as certain forms of strangulation may involve less force. Third, there were major variations in subject characteristics among articles. For instance, some articles included only patients who received certain methods of imaging or presented with certain levels of consciousness. Consequently, there was significant heterogeneity in the clinical severity of presentations within patient populations across articles, as reflected by a mean GCS ranging from 3 to 14 and mortality rates spanning from 0% to 90.4%. This heterogeneity was also seen in imaging methods, with older articles favoring radiographs and newer ones relying more on CT, CT-angiography, and MRI. Many articles bypassed imaging by ruling out injury with examination alone, leading to potentially missed findings. Finally, inconsistencies in injury definitions across articles posed challenges in categorization; for example, certain articles labeled injuries as "laryngotracheal fracture" without specifying the damaged cartilage or bone. As a result, the reported percentages for each type of injury may not accurately reflect the overall study population.

Conclusion

Among patients who survive ED arrival after experiencing a nonjudicial hanging event, the injury rates to structures in the neck are low, with the most frequent being the airway at approximately 5% of cases. Injury was noted more frequently in the adult population as compared to pediatric patients. The medical significance of these noted injuries varied from inconsequential to life-threatening. Additional investigation into this patient presentation is needed to more completely define the expected pathologies and thus suggest the most appropriate evaluation.

Author contributions

BS and WB developed the concept and performed the literature search with an article review. BS, AW, MP, GG, and WB participated in the creation of the manuscript, including the text, figures, and table. All authors were involved in the editing and final approval of the manuscript.

Conflicts of interest

None Declared.

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