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Hyoid Fracture and Strangulation

ABSTRACT: Observation of hyoid fracture in skeletonized remains offers potentially valuable information on the history of the skeleton or evidence of foul play, or both. Perimortem hyoid fracture frequently indicates manual strangulation, although ligature strangulation, hanging, and other forms of trauma to the neck cannot be ruled out without additional evidence. Such fractures are rare in children and infants, since the hyoid components are not fully ossified and are more flexible than in adults. Both antemortem and postmortem origins of the fractures must also be considered.

KEYWORDS: forensic science, physical anthropology, hyoid, fracture, strangulation, trauma, skeletons

In December 1988, the Harrison County Sheriff's Office, Pass Christian, Mississippi recovered the skeletal remains and associated clothing of a child in a wooded area within their jurisdiction. Comparison of the remains with dental records by staff at the Louisiana State University Medical Center School of Dentistry in New Orleans, indicated that the skeleton was that of a local Caucasian female born on March 6, 1978. The girl had been reported missing on August 3, 1988. Investigation suggested the strong possibility that foul play had been involved. The remains and associated evidence were forwarded to the FBI laboratories in Washington, D.C., for further study.

Forensic anthropologic analysis revealed that most of the bones of the skeleton were present. Soft tissue and odor were lacking, but light brown, straight, head hair was still preserved. The right side of the cranium was stained brown, suggesting it had been resting on its right side for the majority of the time between death and discovery. Evidence of large carnivore gnawing was found on the distal right tibia diaphysis and associated epiphysis, two metacarpals, and both ends of a left tibia.

All observations on dental maturation, dental eruption, size and fusion of epiphyses, and general bone size were consistent with information provided about the age of the missing child.

The complete lack of soft tissue and odor, extent of bone staining, and preservation of the remains collectively suggested that death occurred shortly after she was reported missing in early August 1988.

No evidence of trauma or foul play was observed other than the postmortem animal chewing. The hyoid was recovered, but showed no evidence of trauma. Both greater horns were unattached to the body.

In preparation for trial, the investigators accepted that no evidence of trauma was found on the skeleton. However, they questioned to what extent the lack of trauma on the skeleton (including the hyoid) was consistent with strangulation. This paper discusses the published literature on the traumatic involvement of the hyoid and related hard tissue of the neck to assess the probabilities involved.

Anatomy and Development

The hard structures of the anterior neck area consist, in descending order, of the styloid processes of the temporal, the hyoid, the thyroid cartilage, and the cricoid cartilage. The hyoid bone (Fig. 1) consists of a body, two lesser horns (cornua) and two greater horns [1]. The bone does not articulate with any other, but is connected to the styloid process of the temporals by the stylohyoid ligaments [2].

The hyoid develops embryologically from the visceral arches, with the greater horns originating from the lateral cartilages of the third visceral arch and the lesser horns from the distal part of Reicher's cartilage. The body arises from the second or third or both visceral arches [3].

The hyoid ossifies from six centers, two each located in the body, lesser horns, and greater horns [4,5]. The lesser horn is connected to the greater horn and the greater horn appears to attach to the body by diarthrotic joints [3]. Ossification of the hyoid begins shortly before birth, with union of the centers of the body, while the greater horns usually begin to ossify during the first year. With increasing age, the components of the hyoid ankylose, but with great variability [6]. Bony fusion of the greater horn and body is rare in an individual under 20 years old. The frequency of fusion increases with advancing adult age [7], but as many as 28% remain unfused in individuals older than 20 years.

Many hyoids, especially those of women, show only unilateral adult fusion [4]. In their study of the hyoids of 225 males and 75 females aged 2 months to 92 years, O'Halloran and Lundy document that, in males, some fusion occurred in 31% of hyoids of individuals age 20 to 29, 60% age 30 to 39, 73% age 40 to 49, 64% age 50 to 59, 86% age 60 to 69 and 75% above age 70. Females showed a higher frequency than males of fusion under the age of 40 but a lower frequency above age 40.

Frequently, portions of the stylohyoid ligament will ossify [8], and, in rare cases, the entire hyoid apparatus can become ossified. Lykaki and Papadopoulos [9] report such a case where complete ossification occurred of the hyoid, styloid process, main keratohyal, secondary keratohyal, and lesser horn.
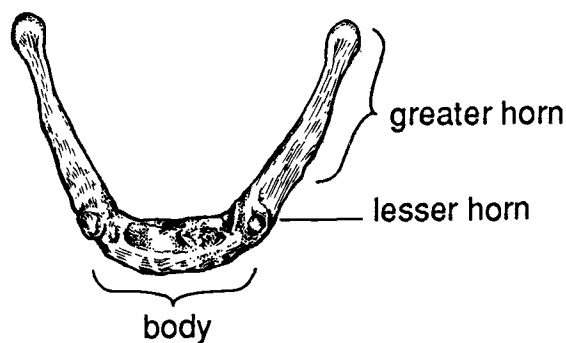

FIG. 1—*The hyoid bone.*

Fracture of the Hyoid

Fracture of the hyoid bone is rare. According to Bouchayer and Dumolard [10], fracture of the hyoid was first noted in 1860. By 1907, only 45 cases of hyoid fracture had been reported from the literature, many as a result of hanging [11]. Guernsey notes that hyoid fractures comprise only .002% of all fractures [12], and are usually associated with fractures of other bones and throat structures. Hyoid fractures have resulted from direct trauma (auto accidents [13], trauma to the neck, for example), strangulation, muscular pressure, and pathologic destruction due to tumors [4]. Olmstead [11] estimates that trauma accounts for 90% of hyoid fractures. Rarely, hyoids can be fractured by forcible swallowing or sudden hyperextension of the neck [12].

In auto accidents and other forms of direct trauma, hyoid fracture is frequently associated with fractures of the mandible, thyroid, and cricoid. Maxeiner [14] reports such a case in which a 15-year-old girl involved in a traffic accident suffered a fracture of the hyoid, temporal, and mandible. Whyte [15] describes another in which a motorcycle accident produced a broken hyoid in association with a fractured mandible. In some cases, it is even possible to make inferences about the direction of the force from the nature of the dislocated skeletal parts [14].

Fractured hyoids originate most commonly from strangulations. These may involve hanging (judicial, accidental, and suicidal), ligature strangulation, and manual strangulation.

Hangings

Bowen [16] reports that at least in London, hanging is becoming an increasingly popular form of suicide, second only to poisoning. Most hangings are suicidal (95%), while a few (5%) are accidental (mostly children caught in clothing or items near beds/cribs or, occasionally, adults performing autoerotic acts).

The literature reports varying frequencies of fracture of neck structures in hangings. According to Spitz and Fisher [17], in hangings, fractures of the hyoid or thyroid are the "exception rather than the rule." Polson and Gee [18] indicate the fracture rate is higher when the knot is at the side of the neck. They note that hyoid fracture is probable in about 14% of all hangings and about 20% of all hangings of individuals over the age of 50. Thyroid fracture is expected in about 50% of all hangings. Polson and Gee note that reports of hyoid fracture with hangings in the literature range from "practically never injured" to "frequent," because the fractured structures are easily overlooked at autopsy.

Individual reports from the literature show considerable variability. Di Maio and Di Maio [19] found, in 83 hangings, no hyoid fractures, 11% with fractured thyroids, and one fractured cervical spine. In 80 cases in Denmark, Simonsen [20] found fractures in 9% of hyoids, 28 percent of thyroid cartilages, and 9% combined fractures. In 61 cases from Seattle, Washington, Luke et al. [21] report fracture of the hyoid in 23% and thyroid fracture in 13%. No cricoid fracture was found. Luke et al. further indicate that the extent of fracturing reflects both the extent of force applied and the degree of ossification of the structures. Iserson [22] reports that, in the United States, hangings account for about 5% of all medicolegal autopsies. In nonjudicial hangings of individuals older than 40 years, the hyoid is fractured in 20% of cases and the thyroid cartilage in about 50%.

Paparo and Siegel [23] indicate that of 167 cases of suicidal hangings in New York between 1972 and 1981, fractures occurred in 6% of hyoids, 11% of thyroids, 0.6% of cricoids, and 3% of thyroid and hyoid combined. They found some form of fracture in 20% of their cases.

In Vienna, Austria, Missliwetz [24] reports that, of 500 suicides by hanging, 71% had fractures of the thyroid or hyoid or both and 2.6% also had fractures of the cricoid.

Collectively, the individual data reported in the above cited literature suggest that, in all hangings, 8% of hyoids are fractured, 15% of thyroids, and only .003% of cricoids. Fracture of the cervical vertebrae appears to be rare and found only when a substantial drop is involved in the hanging [25].

Ligature Strangulation

Ligature strangulation usually is homicidal, but accidental and, rarely, suicidal forms do occur [22]. The literature on autopsies of ligature strangulation victims suggests fractures of neck structures in 13 to 54% of cases [11,19,22,26,27]. Reports that provide information on specific fractured structures [19,26,27] suggest that, of 44 cases, 11% show fractured hyoids, 32% fractured thyroid, and 9% fractured cricoid. Frequently, the ligature is located below the level of the hyoid [6]. The reports indicate that the likelihood of hyoid fracture strengthens with increases in the age of the victim, the width of the ligature, and the pressure with which the ligature is applied [7,18].

Manual Strangulation

Nearly all manual strangulations represent homicides [17,19]. Most authors agree that, in adults, manual strangulations commonly cause fracture of the neck structures, especially in the elderly [17,25,28]. Most also agree that fractures are rare in infants and children [29,30]. Frequencies reported in the literature of fractured bones associated with manual strangulation vary for the hyoid from 17 to 71%, for the thyroid from 50 to 71%, and for the cricoid from 0 to 6% [21,26,29]. This variance likely reflects differences in the ages of the victims, as well as variance in autopsy technique and thoroughness. Collectively, the data suggest that 34% of manual strangulation victims show fractured hyoids, 34% fractured thyroid cartilage, and only 1% fractured cricoid. Line et al. [28] report a similar distribution of fractures in cases from Los Angeles.

Types of Fractures

As noted by Polson and Gee [18], the nature of a fractured hyoid reveals information about the direction and magnitude of causal forces. They note three types: those caused by inward compression, anterior-posterior compression, and avulsion. Experimental research also suggests that the type of fracture in the hyoid is related to its shape [31]. Horizontal fractures are typical in hyperbolic-shaped hyoids while vertical fractures frequently occur in parabolic hyoids.

Difficulty of Detection

During autopsy, fractures of the hyoid can be difficult to detect without very careful dissection. Improper or hasty dissection can even produce a hyoid fracture that may lead to misdiagnosis [30]. Adelson [33] stresses that an antemortem diagnosis should not be made without evidence of recent hemorrhage. Gordon et al. [5] recommend radiography prior to dissection to document hyoid condition. They note that incomplete or fragmented ossification may easily be mistaken for fracture. As noted earlier, the incomplete ankylosis of the greater horns to the body that frequently occurs even in older adults should not be mistaken for fracture [15,32]. It is also possible that the hyoid can be fractured antemortem and not show significant remodeling. Rodriguez [32] reports that hyoid fractures are common in chronic alcoholics.

Interpretation of homicidal trauma through study of damaged neck structures also can be complicated by the possibility of multiple forms of violence on a single victim [33,34].

Moar [34] reports hyoid fracture in a victim who had been kicked, beaten, and stabbed in addition to being strangled.

Skeletonized remains present additional problems for interpretation. Obviously, evidence of hemorrhage, visible in soft tissues, will not be available. The cartilaginous thyroid and cricoid structures usually are not present, although occasionally they will ossify. In skeletonized cases, postmortem trauma must be added to the list of alterations in interpreting recovered hyoid components. The isolated hyoid bone is relatively fragile and easily broken during excavation and the process of recovery. Fresh breaks are normally easily recognized by contrasts of color and texture at the broken surface. However, a postmortem fracture sustained by animal or human activity long before recovery will be difficult to distinguish from perimortem trauma. In this regard, Smith [35] relates an interesting case of a young woman whose hyoid horns and body had not yet united, but who had a fractured right horn. Smith could demonstrate a perimortem origin of the fracture because adipocere had been deposited on the fractured ends.

Discussion

The literature suggests that, in all types of strangulation, the thyroid is the most likely of neck structures to be fractured. Fracture of the hyoid is most common in manual strangulations, in which about 34% of all victims show a fractured hyoid, 34% fractured thyroid and only 1% fractured cricoid. In ligature strangulations, the frequency of hyoid fracture falls to about 11%, compared to 32% thyroid and 9% cricoid. Hangings produce only 8% fractured hyoids, 15% fractured thyroids, and .003% fractured cricoids. The literature strongly suggests that hyoid fracture is uniformly rare in infants and children and becomes more likely with advancing adult age [6,17,18,23,25,29,30,36].

If an incomplete hyoid is found associated with a skeleton, incomplete ossification should first be considered. If the separated margins are clearly irregular and broken, they should be carefully examined for indications of postmortem fracture. If postmortem fracture can be ruled out, inspection for antemortem fracture (which would show remodeling around a broken surface) is in order. Note that antemortem or immediate postmortem fracture can almost never be ruled out entirely on skeletal evidence alone. If a perimortem fracture is suspected then the nature of the fracture may provide some clues regarding the force applied. Statistically, the fracture most strongly suggests manual strangulation, but other forms cannot be ruled out.

In regard to the Mississippi case discussed in the introduction to this manuscript, clearly one would not expect the hyoid to be fractured in a child strangulation. Lack of evidence of hyoid fracture is not inconsistent with the manual or ligature, or both strangulation of a child.

Acknowledgment

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