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Fracture of the Hyoid Bone in Strangulation: Comparison of Fractured and Unfractured Hyoids from Victims of Strangulation

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ABSTRACT: The hyoid is the U-shaped bone of the neck that is fractured in one-third of all homicides by strangulation. On this basis, postmortem detection of hyoid fracture is relevant to the diagnosis of strangulation. However, since many cases lack a hyoid fracture, the absence of this finding does not exclude strangulation as a cause of death. The reasons why some hyoids fracture and others do not may relate to the nature and magnitude of force applied to the neck, age of the victim, nature of the instrument (ligature or hands) used to strangle, and intrinsic anatomic features of the hyoid bone. We compared the case profiles and xeroradiographic appearance of the hyoids of 20 victims of homicidal strangulation with and without hyoid fracture ($n = 10$, each). The fractured hyoids occurred in older victims of strangulation (39 ± 14 years) when compared to the victims with unfractured hyoids (30 ± 10 years). The age-dependency of hyoid fracture correlated with the degree of ossification or fusion of the hyoid synchondroses. The hyoid was fused in older victims of strangulation (41 ± 12 years) whereas the unfused hyoids were found in the younger victims (28 ± 10 years). In addition, the hyoid bone was ossified or fused in 70% of all fractured hyoids, but, only 30% of the unfractured hyoids were fused. The shape of the hyoid bone was also found to differentiate fractured and unfractured hyoids. Fractured hyoids were longer in the anterior-posterior plane and were more steeply sloping when compared with unfractured hyoids. These data indicate that hyoids of strangulation victims, with and without fracture, are distinguished by various indices of shape and rigidity. On this basis, it may be possible to explain why some victims of strangulation do not have fractured hyoid bones.

KEYWORDS: forensic science, forensic medicine, forensic pathology, forensic anthropology, physical anthropology, strangulation, hyoid bone

Homicide by strangulation can occur by compression of the neck by hands (manual strangulation), application of a ligature (ligature strangulation), or direct compression with a blunt instrument. Despite the forensic relevance of detecting strangulation as a method of homicide, relatively few studies on the forensic pathology or anthropology of strangulation have been published since the original paper on the subject by Gonzales in 1933 (1).

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Although many postmortem observations may facilitate the diagnosis of strangulation, fracture of the hyoid bone has significant practical relevance (1,2).

The hyoid bone is a U-shaped bone in the ventral neck that is located superior to the larynx and has major ligamentous connections to the musculature of the neck and tongue. The tips of the hyoid project posteriorly and join the styloid process via the stylohyoid process, which may ossify later in life. The hyoid bone is divided into segments; the lateral portions form the greater cornua or horns, which are continuous with the central portion or body, of the hyoid. The greater cornua and body are separated by various synchrondroses or ossification centers and are associated with variably developed lesser cornua or horns which are found at the site of the junction between the body and greater cornua (3). There are sex and age-dependent differences in hyoid fusion such that the hyoids of women are less likely to fuse than men with advancing age (4). The anatomic position and rigidity of the hyoid make it susceptible to physical injury (fracture) during strangulation.

Fracture of the hyoid bone is a well recognized indicator of strangulation, particularly manual strangulation, and has been less frequently reported in ligature strangulation and hanging (3,5). Although fracture of the hyoid is strongly associated with strangulation, the absence of this observation does not preclude the possibility of manual strangulation. In a recent review of the literature, Ubelaker reported that only 34% of all cases of manual strangulation have a fractured hyoid bone (3). It is likely that many variables determine if a hyoid bone will fracture during strangulation including: (i) magnitude of force applied to the neck; (ii) precise position of the force applied to the neck; (iii) rigidity of the hyoid bone; (iv) age of the victim, (v) nature of the instrument used to strangle (for example, hands or ligature) and possibly (vi) the shape of the hyoid. For example, the hyoid is seldom fractured in children, since the hyoid is flexible due to non-fusion. Similarly, the low frequency of hyoid fracture in hanging may be related to the position of the ligature and/or other mechanical factors including suspension height (5).

In a recent study we have shown that the anatomic variation in hyoid shape is one of the determinants of hyoid fracture in strangulation. In this study of 19 fracture sites in 15 hyoid bones we found that fractures occurred at preferentially vulnerable angles of curvature of the cornu rather than at specific anatomic segments (anterior, middle or posterior orientation). The widely different location of fractures at similar angles of curvature indicates that individual hyoids fracture at specific susceptible angles of curvature along the greater cornu (6).

The various observations on the involvement of the hyoid bone in strangulation leads to a fundamental question: Why do only

some victims of strangulation have hyoid bone fractures? To investigate this issue, we compared fractured and unfractured hyoid bones from victims of strangulation using morphometric parameters derived from xeroradiographs of the hyoid bones. The data indicate that the hyoids of strangulation victims with and without fracture are distinguished by specific indices of shape and rigidity. On this basis, it may be possible to explain why some victims of strangulation do not have fractured hyoid bones.

Materials and Methods

Selection of Cases

Twenty cases of homicide by strangulation (17 women, 3 men, all Caucasian), in which xeroradiography was preformed, occurring in Metropolitan Toronto or surrounding regions between 1983 and 1995, were used for the study. All cases underwent complete medicolegal autopsy under the authority of a Coroner's warrant. In all cases but one, there were petechial hemorrhages of the conjunctivae, recent contusion of the soft tissues and musculature of the neck, and/or superfical abrasions or contusions of the neck. In the exception, advanced decomposition obscured assessment of the eyes and soft tissue of the neck; however, the hyoid was fractured.

Ten of the cases had grossly and/or radiographically detectable fracture of the hyoid bone and ten cases had no gross or radiographic evidence of hyoid bone fracture. In the group of cases with a fracture of the hyoid bone, eight cases were manual strangulations, one case was a ligature strangulation, and a single case was a strangulation using a wooden stick across the front of the neck. Additional autopsy findings of drowning and stab wounds to the chest were found in two cases of manual strangulation. In the group of cases without fracture of the hyoid bone, nine cases were manual strangulations, and one case was a ligature strangulation. Four of the cases of manual strangulations had additional injuries, with one case each showing multiple blunt force injuries, stab wounds of the chest, superfical stab wounds and superfical cutting injuries, respectively. In the two cases of ligature strangulation the ligature was found in situ. Some of the cases used for a previous report were incorporated into this study (6).

Analysis of the Hyoid Bone

In each case the hyoid bone was carefully dissected from the larynx and xeroradiographed in the superior-inferior plane as previously described (6). Fracture of the hyoid bone was determined by xeroradiographic evidence of a discontinuity in the hyoid bone with gross evidence of hemorrhage around the site of fracture. Fusion or ossification of the hyoid bone synchrondroses was determined by inspection of the xeroradiograph. Various morphometric parameters were studied in all 20 hyoids (Fig. 1). The breadth of the hyoid bone, defined as the distance between the tips of the greater cornua was determined by direct measurement of the xeroradiographs. Similarly, the length of the hyoid, defined as the distance from the center of the body of the hyoid bone to the line defining the breadth, was determined from the xeroradiographs. An index of the slope or curvature of the greater cornua was derived from direct analysis of the xeroradiographs. To determine the magnitude of the curvature of the greater cornua, the slope of a line connecting the midpoint of a greater cornu with the tip of a greater cornu was calculated. The status of fracture, ossification, age at death, and the morphometric parameters are reported as means and standard deviations and compared using Student's unpaired two tailed t-test, with $P < 0.05$ considered statistically significant.

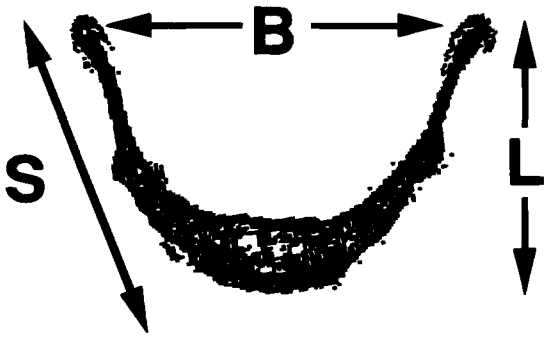

FIG. 1—*Diagrammatic representation of physical dimensions quantified in this study: breadth* (B), *length* (L), *and slope (S).*

Results

Morphometry

The fractured hyoid bones differed from unfractured hyoids by two distinct morphometric parameters. The fractured hyoids were longer in the anterior-posterior plane, and were more steeply sloping than unfractured hyoids (Table 1). Specifically, the magnitude of the slope of the greater cornua in fractured hyoids gave a more distinctive U-shape rather than a V-shape. The breadth (distance between the tips of the greater cornua) was similar for all hyoids, independent of the presence or absence of a fracture. Representative examples of hyoid bone xeroradiographs are shown in Fig. 2.

Age and Fusion of the Hyoid

Analysis of age at death, hyoid fracture and hyoid fusion revealed that hyoid fracture correlated with age and status of fusion (Tables 1 and 2). The majority of victims of strangulation with hyoid fracture had fused hyoids, whereas most without hyoid fracture had unfused hyoid bones. The average age at death of the victims of strangulation with fractured hyoids was similar to the average age of the victims with a fused hyoid. Similarly, the average age at death for victims of strangulation without fractured hyoids was similar to the mean age of the victims with unfused hyoids. This data indicates that age-dependent fusion of the hyoid bone increases the probability of hyoid bone fracture.

TABLE 1—*Dimensions of the hyoid bone from victims of strangulation with and without hyoid fracture.*

Status of Hyoid	Dimensions (mm)		Slope[3]	Fused (%)
	Breadth[1]	Length[2]		
Fractured (n = 10)	37.3 ± 6.2	30.6 ± 4.0†	0.72 ± 0.2†	70
Unfractured (n = 10)	36.3 ± 5.7	24.6 ± 2.7	0.50 ± 0.1	30

[1]Distance between the tips of the greater cornu.
[2]Distance along the anterior-posterior plane from the center of the hyoid body to a point midway between the tip of the greater cornua.
[3]Slope of the line joining a point half way up the horn to the tip of the greater cornu.
†Significant difference between fracture and unfractured hyoids ($P <$ 0.05, Student's unpaired t-test).

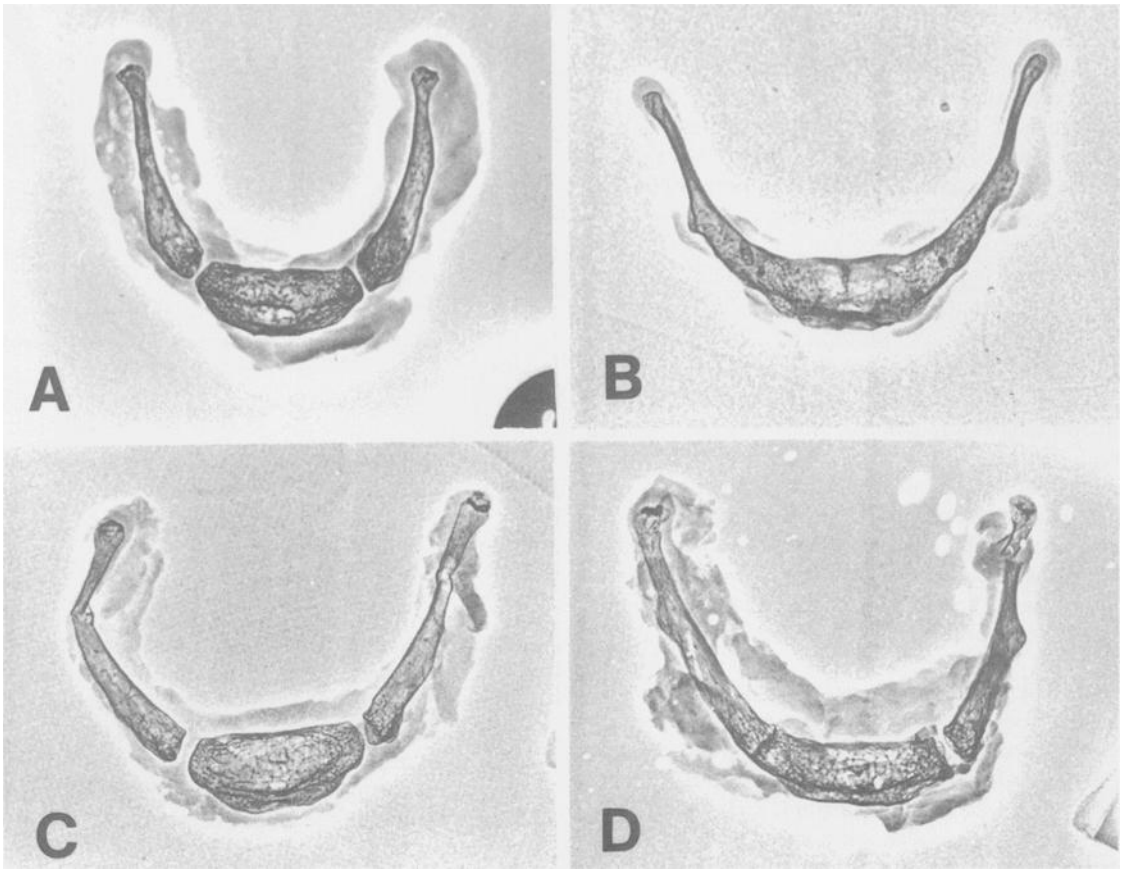

FIG. 2—*Xeroradiographs of various hyoid bones.* (A) *Unfused and unfractured;* (B) *Fused and unfractured;* (C) *Unfused and fractured; and* (D) *Fused and fractured. The anatomic variability of hyoid size and shape is evident.*

TABLE 2—*Relationship between age, hyoid facture and fusion in victims of strangulation.*

	Age of Death	Range of Age
Status of Hyoid†		
Fractured	39 ± 14	18–44
Unfractured	30 ± 10	20–58
Status of Ossification†		
Fused	41 ± 12	18–44
Unfused	28 ± 10	29–58

†Significant difference in mean age between groups of victims ($P < 0.05$, Student's unpaired t-test).

Discussion

The main conclusion of this study is that fracture of the hyoid bone is, at least in part, determined by intrinsic factors of the hyoid bone including rigidity and shape. The findings in our study are consistent with data published by others and may help to clarify some of the statistical results presented in the other studies. In 1987, Srivastava et al. reported the case profiles of 26 cases of strangulation in India (7). In this study, the majority of cases were women (as in our data set), and 25% of the cases had a fractured hyoid bone. In addition, 22% of the female victims of strangulation were 40 years of age or older at the time of death. The concurrence of the proportions of the victims with a fractured hyoid and age greater than 40 is consistent with our data. In our study, the age of hyoid fusion cases coincided with the mean age of strangulation victims that had a hyoid bone fracture. Evaluated together this indicates that, in both studies, victims with hyoid fractures likely had rigid (fused) hyoid bones that were vulnerable to fracture. In another study, James and Silcocks reported that 17% of victims of suicidal hanging had hyoid fractures and that the majority of the victims were over 40 years of age (8). Although the biophysical mechanisms of hanging may differ from manual strangulation, the relationship of age and hyoid fracture in hanging seems to follow the same trend as homicidal strangulations.

The current analysis elucidates a number of potential factors that may predict why some hyoids do not fracture in the course of strangulation. Although the apparant lack of hyoid fracture in children can likely be explained on the basis of hyoid flexibility, the absence of hyoid fracture in a significant proportion of adult victims of strangulation has remained open to speculation. While it is impossible to account for all significant variables that determine hyoid fracture, anatomic features such as hyoid shape are implicated in our study. We found that fractured hyoids had more steeply sloping cornua than unfractured hyoid bones. It is reasonable to speculate that a steeply sloping hyoid bone is more vulnerable to fracture since compressive forces would tend to be concentrated at a localized site of the cornua rather than being uniformly distributed over a relatively curved surface. We also found that fractured hyoid bones were longer than unfractured hyoid bones, but there was no difference in breadth. Since the index of slope used in this study is approximated by the ratio of the length of the hyoid to its

breadth, it would be expected that the magnitude of the hyoid cornual slope differentiates fractured from unfractured hyoid bones. These results indicate that the length of the hyoid bone, in combination with rigidity, is a critical morphometric variable that may determine why some hyoids fracture during strangulation and others remain intact. However, since fractured and unfractured hyoids differed by indices of rigidity and shape it is possible that one of the variables is a confounding parameter.

If the length and slope of hyoid bones can be quantified in a large series of strangulation and hanging victims, it may be possible to derive a quantitative index of "risk of hyoid bone fracture" for individual cases of strangulation. Such an index may prove useful in the practical assessment of individual cases of strangulation were the hyoid is unfractured. This may be of particular importance in assessing evidence of strangulation in potential victims of homicide that are decomposed or have minimal pathologic evidence supportive of strangulation.

The role of polymorphism in the shape and anatomy of the hyoid bone that may be related to sex or race (4) also deserves further study. To evaluate this possibility, a comprehensive quantitative analysis of hyoid bones in a large population would be necessary to determine if structural features of the hyoid bone can divide a population into groups that are more or less vulnerable to hyoid fracture or if there is a continuous spectrum of variation in hyoid structure. Another possible anatomic feature that may ultimately prove to be relevant in hyoid bone fracture is asymmetry of the cornua. Specifically, it is possible that asymmetric hyoid bones are more susceptible to fracture since compressive forces may be preferentially distributed to a single cornu. Analysis with interferometry indicates that this may play an important role in the placement of hyoid fracture sites (9) since distortional forces inferred from this method are non evenly distributed in the stressed hyoid bone.

In summary, we have presented morphometric evidence that some hyoid bones appears to be more vulnerable to fracture than other hyoids that have anatomic features that confer structural stability. Further studies are warranted to clarify the role of polymorphism in hyoid shape and rigidity in hyoid fractures. Ultimately, the morphometric analysis of the hyoid bone in cases of strangulation may augment the postmortem examination of victims of strangulation.

Acknowledgments

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