A Prospective Study of Hyoid Bone Fractures in Fatal Hanging Cases

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Abstract

Background: Fracture of the hyoid bone is a known internal neck anomaly in hanging deaths, but the reported incidence varies considerably due to age distribution, the pattern of hanging, the characteristics of the ligature, the dissection method, and the design of the study.

Objective: To prospectively identify the incidence and distribution of hyoid bone fractures in fatal hanging and study their association with age, sex, suspension, ligature type and knot position.

Methods: A total of 94 consecutive hanging deaths were examined, using a standardized bloodless neck dissection. Hyoid-laryngeal complex was excised in one piece, palpated, dissected and examined for fracture and surrounding haematoma.

Results: The mean age was 33.9 ± 12.7 years and 73 victims (77.7%) were male. 22 cases (23.4%) had a hyoid fracture. The fracture frequency was significantly higher in cases aged ≥40 years compared with those aged <40 years (45.7% vs 10.2%, $p<0.001$). The greater cornu was fractured in 20 of 22 hyoids (90.9%) of which 18 fractures were unilateral and four bilateral. The frequency of fractures was higher in complete suspension compared to partial suspension (28.8% vs 16.7%), but this was not statistically significant. The frequency of fracture did not differ between hard or narrow ligatures and soft or broad ligatures, although hard or narrow ligatures were more common (32.4% vs 18.3%). There was no consistent association between the position of the knot and the side of fracture.

Conclusion: Hyoid fracture was found in about one-fourth of all hanging deaths and was significantly related with older age. Its absence should not be used to preclude hanging and interpretation should be made based on the full picture of the scene, external and internal autopsy.

Keywords: hanging; hyoid bone; fracture; forensic pathology; ligature; autopsy; mechanical asphyxia

Introduction

Hanging is mechanical asphyxia where constriction of the neck is caused by a ligature which is tightened by the weight of the whole body or part of it. Diagnosis in the forensic context is usually based on a combination of the scene, ligature and suspension, external neck mark, internal neck injuries, general asphyxial signs, toxicology and the exclusion of other causes of death. In the internal findings, fractures of the hyoid bone and laryngeal cartilages have been particularly noted as they vary greatly in frequency in the published series.

Early controlled studies showed that prospective examination detects more fractures than retrospective review. Paparo and Siegel found a significantly greater fracture rate in their prospective cases than in their retrospective cases [1]. In 45% of 80 cases of hanging, Simonsen observed fractures of the thyroid cartilage, hyoid bone or both, and reported that the incidence rose with age [2]. Morild also noted that careful dissection and radiographic evaluation improves detection, and that fractures are more common in older victims [3].

In a prospective study, Green et al. reported that 47.5% of suicides by hanging had fractures of neck structures, such as isolated hyoid fractures and combined hyoid-thyroid fractures [4]. Lower and very variable frequencies have been reported in Indian studies. Sharma et al. showed that prospective examination resulted in higher number of neck structure injuries than retrospective documentation [5] and in a subsequent prospective study on constriction deaths, they found hyoid fracture in 21% of cases [6]. In a series of Thai hangings, Charoonnate et al. reported fractures of the hyoid and/or thyroid cartilage in 25%, and emphasized the importance of careful microscopic examination [7].

Age is cited as one of the most consistent factors in hanging neck-skeleton fracture. Reduced elasticity of the hyoid-laryngeal complex, along with increased ossification and fusion, may increase susceptibility to fracture. Other factors proposed to be determinants have had conflicting results, however, including sex, body habitus, complete vs. incomplete suspension, width or hardness of ligature, and position of the knot. Clément et al. determined that age was a significant factor, and that the effect of total suspension increased with age of victim [8]. Nikolić et al. also reported a high incidence of hyoid-laryngeal fractures and investigated the correlation between the position of the knot and the occurrence of these fractures [9].

Technique is a major factor in the reliability of fracture detection. In an Indian autopsy study, Jayaprakash and Sreekumari reported relatively low frequencies of hyoid and thyroid cartilage fracture with extensive external findings [10]. After reviewing the literature, Khokhlov found that the wide variation in reported fracture incidence was in part methodological and that full preparation of the laryngohyoid complex is much more sensitive than palpation or limited dissection [11]. Normal anatomical variations and incomplete fusion of greater cornua with the hyoid body can also cause confusion in interpretation, and may simulate fracture. The irregular and age-dependent fusion patterns are presented by the population data from Northwest India [12].

The heterogeneity was also observed in more recent series (pre-2017). In the city of Shanghai, Ma et al. found fractures in only a small number of hanging and strangulation cases [13], while Hlavaty et al. noted that there were fewer internal neck injuries in both retrospective and prospective samples of hanging and strangulation [14]. These disparities further underscore the importance of prospective, standardised examination in the specific setting of individual medicolegal cases. The present study aimed to identify the frequency and anatomical pattern of hyoid bone fractures in consecutive cases of homicidal hanging and to evaluate the relationship between hyoid bone fracture and age, sex, type of suspension, ligature characteristics and position of the knot.

Materials and Methods

The study design was prospective descriptive autopsy study conducted in the Department of Forensic Medicine and Toxicology of a tertiary teaching hospital. A total of 10 consecutive cases were examined where the police inquest, scene and autopsy findings all agreed that the death was by hanging.

Eligibility criteria: Cases of complete and partial neck hanging of both sexes and all age groups were included where the neck structures were sufficiently preserved for detailed examination. Bodies with advanced decomposition, extensive burns and/or significant destructive neck trauma, other than suspension, and bodies in which the hyoid-laryngeal complex had been surgically removed prior to death and/or where there was insufficient scene/inquest information were excluded. Ligature strangulation was not excluded with confidence in cases and was excluded and these cases were also not included.

External examination: If present, the width, consistency and number of turns of the ligature material were recorded. The ligatures were classified for analysis into soft/broad (cloth, sari, dupatta, bed sheet) and hard/narrow (rope, nylon cord, electric wire, or other narrow material). The ligature mark was described with respect to level, direction, continuity, parchmentization and relationship to thyroid cartilage. The position of the knot was classified as posterior/occipital, right lateral, left lateral, or anterior. Suspension was considered complete when the body was fully unsupported and partial when any part of the body made contact with a supporting surface.

Neck dissection and hyoid examination: After completion of the cranial and thoracoabdominal examination, a bloodless layer-by-layer dissection of the neck was performed to minimize artefactual haemorrhage, and then the hyoid was examined. Haemorrhage was examined in the sternocleidomastoid and strap muscles. The carotid sheaths and vessels were examined. The tongue, hyoid bone, larynx, upper trachea and surrounding soft tissues were excised en bloc. The hyoid was carefully dissected without any forceful manipulation. The greater cornua, body and the junctures of the body and cornua were examined and lightly palpated. Only when there was definite cortical discontinuity and abnormal mobility with a tissue reaction/haemorrhage and no features of a normal

non-fused joint was a fracture recorded. The fracture site, side, unilateral/bilateral pattern and associated thyroid cartilage injury were recorded.

The primary outcome was hyoid fracture, assessed via variables and statistical analysis. The associations of age (<40 years vs. ≥40 years), sex, suspension type, ligature category and knot position were analysed by chi-square or Fisher's exact test. Data are presented as mean ± SD. A p value <0.05 was considered statistically significant.

Results

Ninety-four consecutive hanging deaths fulfilled the inclusion criteria. There were 73 males (77.7%) and 21 females (22.3%), with a male-to-female ratio of 3.5:1. Age ranged from 15 to 72 years and the mean age was 33.9 ± 12.7 years. Fifty-nine victims (62.8%) were younger than 40 years. Complete suspension was present in 52 cases (55.3%) and partial suspension in 42 (44.7%). Soft or broad ligatures were used in 60 cases (63.8%), while hard or narrow ligatures were used in 34 (36.2%). The knot was posterior/occipital in approximately half of the cases.

Table 1. General characteristics of fatal hanging cases

Variable	Category	n	%
Sex	Male	73	77.7
	Female	21	22.3
Age group	<40 years	59	62.8
	≥40 years	35	37.2
Suspension	Complete	52	55.3
	Partial	42	44.7
Ligature type	Soft/broad	60	63.8
	Hard/narrow	34	36.2
Knot position	Posterior/occipital	48	51.1
	Right lateral	19	20.2
	Left lateral	17	18.1
	Anterior	10	10.6

Hyoid bone fracture was identified in 22 cases (23.4%). The greater cornu was the fracture site in 20 cases (90.9% of fractured hyoids), whereas two fractures involved the body close to the cornu-body junction. Eighteen fractures were unilateral and four bilateral. Among unilateral fractures, 10 were right-sided and eight left-sided. Associated thyroid cartilage fracture was found in eight of the 22 cases with hyoid fracture. Haemorrhage in the strap muscles was present in 32 cases (34.0%), sternocleidomastoid haemorrhage in 24 (25.5%), and carotid intimal injury in two (2.1%).

Table 2. Pattern of hyoid and associated neck injuries

Finding	n	%
Any hyoid fracture	22	23.4
Greater cornu fracture	20	21.3
Hyoid body/cornu-body junction fracture	2	2.1
Unilateral hyoid fracture	18	19.1
Bilateral hyoid fracture	4	4.3
Associated thyroid cartilage fracture	8	8.5
Strap muscle haemorrhage	32	34.0
Sternocleidomastoid haemorrhage	24	25.5
Carotid intimal injury	2	2.1

Age showed the strongest association with hyoid fracture. Sixteen of 35 victims aged 40 years or older had a fracture compared with six of 59 younger victims (45.7% vs 10.2%; $p<0.001$). Fracture frequency was higher in complete than partial suspension (28.8% vs 16.7%) and in hard/narrow than soft/broad ligatures (32.4% vs 18.3%), but these differences did not reach statistical significance. Male and female fracture frequencies were similar after allowing for the small number of female cases. Knot position was not significantly related to fracture occurrence, and the side of fracture did not show a reproducible relationship with the side of the knot.

Table 3. Association of selected variables with hyoid fracture

Variable	Hyoid fracture present	Hyoid fracture absent	p value
Age <40 years (n=59)	6 (10.2%)	53 (89.8%)	<0.001
Age ≥40 years (n=35)	16 (45.7%)	19 (54.3%)	
Male (n=73)	18 (24.7%)	55 (75.3%)	0.677
Female (n=21)	4 (19.0%)	17 (81.0%)	
Complete suspension (n=52)	15 (28.8%)	37 (71.2%)	0.166
Partial suspension (n=42)	7 (16.7%)	35 (83.3%)	
Hard/narrow ligature (n=34)	11 (32.4%)	23 (67.6%)	0.116
Soft/broad ligature (n=60)	11 (18.3%)	49 (81.7%)	
Posterior knot (n=48)	8 (16.7%)	40 (83.3%)	0.244
Lateral/anterior knot (n=46)	14 (30.4%)	32 (69.6%)	

Discussion

In the present prospective study, 23.4% of hanging deaths were found to have hyoid fractures. This frequency falls within the broad range described in forensic literature and is a representative example of the wide range of frequencies reported and why fracture should not be considered as an obligatory feature of hanging. Paparo and Siegel demonstrated that fracture rates increase when cases are examined prospectively and systematically [1]. Laryngohyoid fractures were reported by Simonsen in 45% [2] and by Morild, who carefully dissected and radiographed the area, who also reported a relatively high incidence [3]. In contrast, several Indian and international series have reported much lower rates. Much of this variation is likely to be attributable to the differences in study design, age distribution, dissection method, and definition of fracture.

Age was the best correlation in the current study. Hyoid fracture occurred in nearly half of victims 40 years or older, but in about one in ten victims younger than 40. This is in line with the observations made by Simonsen [2], Morild [3], Green et al. [4] and Clément et al. [8]. The hyoid-laryngeal complex is less elastic with age due to progressive ossification and variable fusion, and is more susceptible to mechanical loading. When comparing studies, it is important to take into account the

age effect: if one study includes a large number of young adults, the fracture frequency will be lower than a study that includes a large number of older adults, even if other factors are the same.

Care should also be taken with normal variation in fusion of the greater cornua. In Northwest Indians, Harjeet et al. demonstrated that the fusion patterns of the hyoid bones were irregular and fusion may not be complete even in older individuals [12]. If the hyoid is only palpated or manipulated forcefully, the unfused synchondrosis can be confused with a fracture at autopsy. The fractures in the present study were only accepted if there was definite discontinuity and abnormal mobility, associated with local tissue reaction or haemorrhage and if the appearance was not compatible with a normal joint. The conservative approach was meant to minimize false positive classification.

Fractured hyoids occurred in 90.9% of the cases at the greater cornu. This distribution is to be expected, as the greater cornua are subjected to the forces of traction and bending when the ligatures are compressed in the thyrohyoid membrane and through the surrounding soft tissues. Both isolated hyoid fractures and hyoid-thyroid injuries were reported by Green et al. [4]. The authors of another study, Charoonnate et al., also noted the importance of careful examination, as some hyoid fractures may not be detectable by routine visual and palpatory examination [7].

In our series, complete suspension had a higher fracture frequency than partial suspension, but this was not statistically significant. Clément et al. have determined that the effect of complete suspension was more pronounced for older subjects [8] implying interaction between intrinsic tissue stiffness and loading magnitude and/or direction. In their comparative study Sharma et al. [5] noted that in atypical complete hangings, neck-structure fractures were more common. The simple dichotomy of complete/partial hangings is not able to capture the mechanical load on the hyoid, as many partial hangings still impose significant forces on the neck.

Narrow or hard ligatures created a greater number of hyoid fractures than broad or soft ligatures. This association was not statistically significant, however. There are conflicting published reports on this. Some series indicate that the type of ligature may exert greater pressure, while others indicate that age and suspension may be more important than the type of ligature. Sharma et al. observed that soft articles of clothing were commonly used in hanging yet fractures still occurred [6]. Ligature texture should thus be viewed as one of the factors that may contribute to fracture, and not as a cause of fracture.

There was no consistent association between side of fracture and knot position. Nikolić et al. investigated if hyoid-laryngeal fractures would be a good predictor of the location of the knot and found that hyoid fracture alone was not a good predictor [9]. Our observations are in agreement. The direction of the hanging force is not only determined by the knot but also by the body position, the movement at the time of hanging, the course of the ligature, the neck anatomy, and partial support. Therefore, a single fracture should not be relied upon alone for a reconstruction of knot position.

The overall distribution of internal neck injuries in this study also highlights that hyoid fracture is just one element of the autopsy diagnosis. The incidence of strap muscle haemorrhage and sternocleidomastoid haemorrhage was higher than hyoid fracture, while the incidence of carotid intimal injury was lower. Jayaprakash and Sreekumari also noted that there is a need to connect external and internal findings, and that the frequency of hyoid and thyroid cartilage fracture was low, but with characteristic ligature marks [10]. Similarly, fractures were only observed in a few hanging and strangulation cases by Ma et al. [13].

There is a great deal of variation in methodology. In Khokhlov's review, significant differences in sensitivity were found between palpation, radiography and full preparation of the laryngohyoid complex [11]. Hlavaty et al. also emphasized that in some cases, the prevalence of internal injuries reported in contemporary series can be very different from that reported in series where hanging is well documented [14]. These results should not be used as a one-size-fits-all diagnostic tool, as a published fracture percentage may not apply to everyone. Technically sound neck dissection and interpretation in context is required for each case.

The study has some limitations. It was carried out at one medicolegal centre with a moderate number of cases. The analysis was based on general categories of ligatures, which may not reflect exact mechanical characteristics of ligatures (e.g., width, elasticity, tightness of knot, surface friction). Not always available body weight and exact suspension height. Not all specimens were subjected to microradiography or stereomicroscopy. However, the design, the standardized neck dissection, and the clear differentiation between fracture and normal non-fusion increase the internal validity of the observations.

The absence of a hyoid fracture should therefore not be considered as a negative sign of hanging, and the presence of a fracture should not be taken as a positive sign of hanging. Other neck compressions and sometimes trauma can cause hyoid fractures. The most definitive determination in a suspected hanging death is a combination of scene findings, ligature characteristics, external mark, soft-tissue injury, hyoid-laryngeal examination, toxicology and the exclusion of competing causes.

Conclusion

The fracture of the hyoid bone was found in 23.4% of the cases of hanging, which were examined prospectively, and was most frequently of the greater cornu. The most obvious associated factor was increasing age; fractures were significantly more common in victims 40 years of age or older. The fracture proportions were higher for complete suspension and hard or narrow ligatures, but these differences were not statistically significant, and knot position was not a reliable predictor of fracture occurrence or side. Thus, hyoid fracture is a supportive but non-obligatory autopsy finding in hanging. The bloodless dissection of the neck is important and awareness of normal variants of hyoid fusion is critical, and a diagnosis should not be made based on the presence or absence of one fracture alone, but on the entire medicolegal context.

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