

Morphological Typology and Qualitative Anatomical Variants of the Adult Human Hyoid Bone: Forensic and Clinical Implications

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Abstract

Background: The human hyoid bone demonstrates substantial macroscopic structural polymorphism. Although classically described as a uniform U-shaped structure, its morphological configurations vary considerably across populations. Recognizing these qualitative anatomical variants is essential for forensic identification, medicolegal trauma interpretation, and surgical planning in head and neck procedures.

Aims & Objectives: To evaluate the distribution and frequency of morphological shape typologies of the adult human hyoid bone, determine their correlation with biological sex and regional demography, and analyze qualitative anatomical variations.

Material & Methods: A prospective post-mortem anatomical investigation was carried out on 100 excised, cleaned, and dried adult human hyoid bones (60 males, 40 females; age range: 40–83 years). Specimens were systematically classified into distinct qualitative morphological variants: V-shaped, U-shaped, D-shaped, Boat/B-shaped, and Horseshoe (HK)-shaped. Associations between morphological typologies, biological sex, and residential background were evaluated using Pearson's Chi-square tests (χ^2) and Fisher's exact tests ($p < 0.05$).

Results: V-shaped (42.0%) and U-shaped (42.0%) geometries predominated, accounting for 84.0% of the entire sample, followed by D-shaped (7.0%), Boat/B-shaped (4.0%), Horseshoe (HK)-shaped (4.0%), and a rare atypical H-type variant (1.0%). A highly significant association was identified between hyoid shape typology and biological sex ($\chi^2 = 38.641, p < 0.001$). V-shaped morphology predominated heavily in males (66.7% vs. 5.0% in females), whereas U-shaped morphology predominated in females (67.5% vs. 25.0% in males). Rural and urban residential backgrounds showed no statistically significant divergence in shape distribution ($\chi^2 = 5.24, p = 0.387$).

Conclusion: Qualitative macroscopic typology of the hyoid bone exhibits marked sexual dimorphism. Morphological classification provides a rapid, accessible adjunct for forensic sex screening and offers critical anatomical awareness for head and neck surgeons.

Keywords: Hyoid Bone; Morphological Typology; Anatomical Variants; Forensic Anthropology; Neck Compression Trauma; Skeletal Variation.

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Introduction

Personal identification and biological profiling from skeletal remains represent core responsibilities within forensic anthropology and legal medicine [1,2]. While standard osteometric measurements of major bones are widely utilized, qualitative morphological traits provide rapid, non-destructive screening tools at the autopsy table [3,4]. Among skeletal elements, the

hyoid bone possesses a distinct anatomical profile characterized by high phenotypic variability [5,6].

In standard anatomical nomenclature, the hyoid is traditionally portrayed as a symmetrical, U-shaped bone located in the anterior neck at the level of the third cervical vertebra (C3) [7,8]. However, embryological development from the second and third branchial arches involves multiple asynchronous chondrification and ossification centers [9,10]. The

variable fusion timing of the greater cornua to the central body, combined with differential muscular traction from suprahyoid and infrahyoid muscle complexes, produces a wide array of morphological shapes [11,12].

Categorizing hyoid shape typologies carries practical importance across three primary domains:

1. **Forensic Anthropology:** Qualitative shape categorization serves as an immediate indicator during initial skeletal sorting and biological sex screening before formal metric analysis [13,14].
2. **Forensic Pathology & Trauma Analysis:** The structural geometry of the hyoid directly influences how mechanical forces are distributed during neck compression trauma, such as manual strangulation or hanging [15,16]. Angular configurations respond differently to compressive loads compared to parabolic arches [17,18].
3. **Clinical and Surgical Practice:** Head and neck procedures—including hyoid suspension for obstructive sleep apnea (OSA), Sistrunk procedures for thyroglossal duct cyst excision, and neck dissections—rely heavily on precise anatomical orientation [19–21]. Recognizing normal and atypical morphological variants prevents iatrogenic nerve injury or vascular complications [22,23].

This study investigates the prevalence, distribution, and sex-based segregation of qualitative morphological hyoid typologies in an adult autopsy cohort.

Material and Methods

Sample Collection & Processing

A total of 100 intact adult human hyoid bones (60 males, 40 females; age range: 40–83 years) were collected during routine medicolegal autopsies after obtaining clearance from IEC. All cases possessed verified chronological age, biological sex, and demographic documentation. Specimens with antemortem or perimortem neck fractures, destructive bone pathologies, or severe osteoporosis were excluded.

During neck evisceration, the hyoid bone was excised en bloc. Attached soft tissues, suprahyoid and infrahyoid musculature, and thyrohyoid membranes were meticulously cleaned. Bones underwent mild enzymatic maceration, were rinsed thoroughly under running water, and were air-dried at ambient room temperature.

Qualitative Morphological Classification Framework

Each dried specimen was placed in an anatomical resting position on a flat horizontal plane. Following

established anthropological and anatomical criteria [5,6,25], specimens were categorized into specific qualitative shape typologies:

- **V-Shaped:** Greater cornua converge sharply toward the anterior body, forming an acute angle with a distinct, angular anterior body apex.
- **U-Shaped:** Greater cornua run in a parallel or gently divergent parabolic curve, terminating in a rounded anterior body arch.
- **D-Shaped:** An asymmetrical configuration where one lateral horn arches outward while the anterior body base is flattened or compressed.
- **Boat / B-Shaped:** An elongated, shallow configuration resembling a skiff or keel, featuring a broad body and widely splayed cornua.
- **Horseshoe (HK)-Shaped:** A curved, semicircular configuration characterized by inward-pointing terminal cornual tips.
- **Atypical (H-Type / Irregular):** Unusual configurations lacking standard bilateral symmetry or exhibiting anomalous fusion patterns.

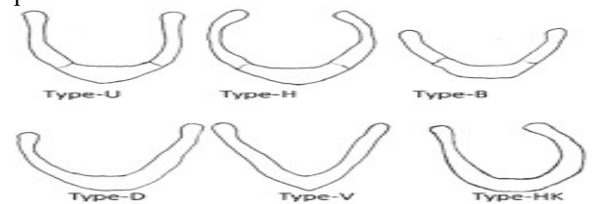


Figure 1: Showing shapes of hyoid bone

Statistical Analysis

Data were analyzed using standard statistical software's. Categorical variables were expressed as absolute frequencies and percentages. Associations between morphological shape typologies, biological sex, and residential background (rural versus urban) were evaluated using Pearson's Chi-square tests (χ^2) and Fisher's exact tests. The threshold for statistical significance was established at $p < 0.05$.

Results

Overall Prevalence of Morphological Typologies

Among the 100 examined adult specimens, V-shaped (42/100, 42.0%) and U-shaped (42/100, 42.0%) typologies dominated the cohort, jointly accounting for 84.0% of all observations. Alternative configurations comprised D-shaped (7.0%), Boat/B-shaped (4.0%), Horseshoe (HK)-shaped (4.0%), and a single atypical variant (1.0%).

Distribution of Hyoid Morphological Typologies by Biological Sex

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Morphological Typology	Male (n=60) Count (%)	Female (n=40) Count (%)	Total Sample (N=100) Count (%)	Sex Predominance / Pattern
V-Shape d	40 (66.7%)	2 (5.0%)	42 (42.0%)	Strongly Male-Predominant
U-Shape d	15 (25.0%)	27 (67.5%)	42 (42.0%)	Strongly Female-Predominant
D-Shape d	2 (3.3%)	5 (12.5%)	7 (7.0%)	Female-Predominant
Boat / B-Shape d	1 (1.7%)	3 (7.5%)	4 (4.0%)	Female-Predominant
Horse shoe (HK)	2 (3.3%)	2 (5.0%)	4 (4.0%)	Balanced Distribution

Morphological Typology	Male (n=60) Count (%)	Female (n=40) Count (%)	Total Sample (N=100) Count (%)	Sex Predominance / Pattern
Atypical (H-Type)	0 (0.0%)	1 (2.5%)	1 (1.0%)	Rare Variant
Total	60 (100.0%)	40 (100.0%)	100 (100.0%)	$\chi^2 = 38.641$ < 0.001

Cross-tabulation revealed a highly significant association between hyoid morphological shape and biological sex ($\chi^2 = 38.641, df = 5, p < 0.001$). V-shaped morphology was observed in two-thirds of male specimens (66.7%), but in only 5.0% of females. Conversely, U-shaped morphology predominated among females (67.5%), compared to 25.0% among males.

Demographic Distribution and Residential Background

Evaluating morphological typologies against residential background (rural versus urban) revealed no statistically significant geographic clustering ($\chi^2 = 5.24, p = 0.387$):

- **Rural Subgroup (n = 65):** V-shaped (25), U-shaped (29), D-shaped (5), Boat/B-shaped (4), HK-shaped (1), Atypical (1).
- **Urban Subgroup (n = 23):** V-shaped (11), U-shaped (8), HK-shaped (3), D-shaped (1).
- **Unknown Residence (n = 12):** V-shaped (6), U-shaped (5), D-shaped (1).

Age distributions across morphological shapes showed no significant differences (Kruskal-Wallis $H = 2.14, p = 0.543$), indicating that shape typologies remain stable across adult age brackets from the fourth through ninth decades of life.

Discussion

Macroscopic classification of skeletal variants is a fundamental component of forensic anthropology and

clinical anatomy [3,5]. Although classical anatomical literature frequently portrays the hyoid bone as universally U-shaped [7,8], our findings demonstrate that adult populations display significant qualitative geometric diversity [6,25].

Sexual Dimorphism of Morphological Typologies

The most striking finding of this study is the pronounced sexual dimorphism associated with hyoid shape configurations ($\chi^2 = 38.641, p < 0.001$). V-shaped configurations were heavily concentrated among males (66.7%), whereas U-shaped configurations predominated among females (67.5%). This structural divergence is directly related to sexual dimorphism within the laryngeal cartilaginous framework [9,12]. During pubertal maturation, hormonal influences—specifically testosterone—drive significant anterior and lateral expansion of the thyroid cartilage in males, generating an acute thyroid angle ($\sim 90^\circ$ in males vs. $\sim 120^\circ$ in females) [10,26]. Because the anterior body of the hyoid anchors the thyrohyoid membrane and median thyrohyoid ligament, the acute anterior projection of the male thyroid cartilage exerts continuous mechanical traction on the hyoid body, pulling its lateral cornua into an acute V-shape [27,28]. In contrast, the wider female thyroid angle supports an open, parabolic U-shape [5,25].

Asymmetrical and Atypical Variants

In addition to standard V- and U-shapes, 16.0% of the cohort exhibited alternative configurations, including D-shaped, Boat/B-shaped, and Horseshoe forms. Asymmetrical D-shaped hyoids (7.0%) typically arise from developmental asymmetries in muscular pull or unilateral differences in the timing of synostosis between the greater cornua and body [11,29]. Boat-shaped variants (4.0%) reflect hypoplastic or narrower cornual development [30]. Recognizing these alternate morphologies is clinically critical to prevent radiologists and surgeons from misinterpreting normal anatomical variants as perimortem fractures, congenital pathology, or destructive bone lesions [31,32].

Biomechanical Implications in Neck Compression Trauma

Qualitative morphological classification carries vital medicolegal significance during the forensic investigation of fatal asphyxial violence [15,16]. When compressive forces are applied to the neck during manual strangulation or ligature hanging, the load is transmitted directly to the hyoid bone [17,33].

- **V-Shaped Hyoids:** Because the greater cornua converge at an acute angle, they possess a narrower elastic arc. When inward compressive pressure exceeds structural tolerance, acute-angled bones are more vulnerable to sudden snapping or

displacement, particularly in older adults with fully ossified synostoses [16,18,34].

- **U-Shaped Hyoids:** The broader, rounded parabolic curve allows compressive forces to dissipate more effectively across a wider elastic span, conferring greater structural resilience against blunt deformation [17,35].

Understanding these shape-dependent biomechanical differences assists forensic pathologists in evaluating why skeletal trauma occurs in certain neck structures while sparing others [15,33,36].

Surgical and Clinical Relevance

Awareness of hyoid morphological variants is essential across several surgical disciplines:

- **Obstructive Sleep Apnea (OSA) Surgery:** Procedures such as hyoid suspension and hyomandibulopexy involve direct skeletal manipulation, wire fixation, or suture passage through the hyoid body [19,37]. Surgeons operating on a narrow V-shaped hyoid encounter a restricted working surface, increasing the risk of suture cut-through or accidental penetration into the pre-epiglottic space [20,38].
- **Thyroglossal Duct Cyst Excision (Sistrunk Operation):** The standard Sistrunk procedure mandates central hyoid body resection [21,39]. Encountering atypical or asymmetrical hyoid configurations requires careful dissection to ensure complete excision of the thyroglossal tract while avoiding injury to the hypoglossal nerve and lingual vessels [22,40].

Comparison with Contemporary Literature

The qualitative morphological distributions observed in this study align closely with findings reported in recent international literature:

- Leksan et al. [5] established a multi-class shape categorization, noting a strong male predilection for narrow angular forms and female predilection for broad parabolic arches.
- 3D computed tomography investigations by Shimizu et al. [25] and Torimitsu et al. [41] confirmed that anterior body contour and cornual divergence successfully separate male and female specimens in Asian cohorts.
- Regional autopsy series from South Asia by Bhardwaj et al. [42], Savitha et al. [43], and Jha et al. [44] similarly reported that V-shaped and U-shaped hyoids account for over 80% of anatomical configurations, with atypical variants occurring in 10% to 15% of cases.

Limitations

Visual and qualitative categorization of bone geometry involves subjective evaluation of complex continuous shapes. Future investigations utilizing 3D geometric morphometrics, surface laser scanning, and Procrustes landmark superimposition will enable even more rigorous digital mapping of these anatomical variants.

Conclusion

The adult human hyoid bone demonstrates substantial qualitative morphological variability, with V-shaped (42.0%) and U-shaped (42.0%) configurations predominating, alongside less frequent D-shaped, Boat-shaped, and Horseshoe variants. Hyoid shape typology exhibits marked sexual dimorphism: V-shaped configurations are heavily concentrated in males (66.7%), whereas U-shaped configurations predominate in females (67.5%). Awareness of these morphological variants provides rapid qualitative criteria for forensic sex screening, explains structural vulnerability patterns in neck compression trauma, and guides head and neck surgeons during cervical procedures.

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