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Anatomical Variations of the Styloid Process: A Cadaveric Morphometric Study and Clinical Significance.

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Abstract:

Background: The styloid process, a bilateral bony projection of the temporal bone, is anatomically related to critical neurovascular structures in the head and neck. Elongation, exceeding 30mm, has been implicated in various neurological and vascular symptoms. This study aims to analyze the morphometric parameters of the styloid process in cadavers and correlate these findings with clinical implications.

Aim and Objectives: To measure the morphometric parameters (length and breadth) of the styloid process in human cadavers and dry skulls, to determine the prevalence of elongated styloid processes, and to discuss the potential clinical effects of such elongation.

Materials and Methods: This observational, descriptive study analyzed styloid processes retrieved from 40 human cadavers and 15 dry skulls from the anatomy department of the institution. Morphometric measurements, including length and breadth, were recorded. The spatial orientation of structures adjacent to the styloid process was examined, and any deviations were documented.

Results: A total of 110 styloid processes were studied. Four elongated styloid processes were identified, yielding a prevalence rate of 3.6%. The mean lengths were 16.1 mm on the right and 16.07 mm on the left, with the right side exhibiting slightly longer processes. The mean breadths were 5.7 mm on the right and 5.13 mm on the left.

Conclusions: Identifying elongated styloid processes is crucial for diagnosing Eagle's syndrome. This study contributes to the understanding of styloid process morphometry, providing valuable information for head and neck surgeons and radiologists. The findings highlight the importance of considering styloid process variations in the differential diagnosis of related clinical symptoms.

Introduction

The styloid process (SP), a slender, pointed bony projection extending anteroinferiorly and medially from the undersurface of the temporal bone, is a structure of significant anatomical and clinical importance. Its proximity to vital neurovascular structures in the head and neck region renders its morphology, particularly its length and orientation, crucial in understanding various clinical manifestations. This introduction will delve into the anatomical intricacies of the styloid process, its embryological origins, its clinical relevance, and the need for comprehensive morphometric analyses. Embryologically, the styloid process originates from

the second branchial arch, also known as Reichert's cartilage. This cartilaginous structure undergoes a complex process of ossification, ultimately contributing to the formation of the styloid process, the stylohyoid ligament, and the lesser cornu of the hyoid bone. Disruptions or variations during this ossification process can lead to significant morphological differences in the mature styloid process, including variations in length, angulation, and the degree of ossification of the stylohyoid ligament. Anatomically, the styloid process projects from the temporal bone, situated just anterior to the stylomastoid foramen. It serves as an attachment point for several muscles and ligaments, including the stylohyoid muscle, styloglossus muscle, stylopharyngeus muscle, and the stylohyoid ligament. These structures play essential roles in functions such as swallowing, speech, and tongue movement. The close spatial relationship of the styloid process with critical neurovascular structures, such as the internal and external carotid arteries, the jugular vein, and cranial nerves IX, X, and XI, highlights its clinical relevance. The normal length of the styloid process has been a subject of debate. While a range of 25-30mm is often cited, significant variations have been reported across different populations. An elongated styloid process, typically defined as exceeding 30mm in length, is a common finding in radiological studies and has been associated with a clinical condition known as Eagle's syndrome. Eagle's syndrome, first described by Watt Weems Eagle in the 1930s, is a condition characterized by cervicofacial pain, dysphagia, globus sensation, tinnitus, and other related symptoms. These symptoms are attributed to the compression or irritation of surrounding neurovascular structures by an elongated or abnormally angulated styloid process. The clinical presentation of Eagle's syndrome can be highly variable, often mimicking other conditions such as temporomandibular joint disorders, neuralgia, and pharyngitis. This diagnostic challenge underscores the importance of accurate anatomical knowledge and reliable diagnostic methods. The pathogenesis of Eagle's syndrome is not fully understood, but several theories have been proposed. One theory suggests that an elongated styloid process can impinge on the glossopharyngeal nerve, causing pain along its distribution. Another theory posits that the elongated process can compress the carotid arteries, leading to carotidynia and related vascular symptoms. Furthermore, ossification of the stylohyoid ligament can contribute to the development of Eagle's syndrome by creating a rigid bony structure that impinges on surrounding tissues. Radiological evaluation plays a crucial role in the diagnosis of styloid process-related pathologies. While traditional radiographic techniques such as panoramic radiography and lateral cephalometry can provide some information, they have limitations in accurately assessing the length, angulation, and spatial relationships of the styloid process. Multi-detector computed tomography (MDCT) and cone-beam computed tomography (CBCT) have emerged as the gold standards for evaluating the styloid process, offering superior spatial resolution and multiplanar reconstruction capabilities. Morphometric analysis of the styloid process is essential for understanding its anatomical variations and their clinical implications. Previous studies have reported significant variations in the length and angulation of the styloid process across different populations. However, there is a need for further research to provide comprehensive morphometric data and to correlate these findings with clinical presentations. Cadaveric studies offer a unique opportunity to directly examine the styloid process and its surrounding structures. They provide valuable insights into the anatomical variations and spatial relationships that are difficult to assess using radiological techniques alone. By performing detailed morphometric measurements and examining the spatial orientation of adjacent structures, cadaveric studies can contribute to a better understanding of the clinical implications of styloid process morphology. This study aims to perform a detailed morphometric analysis of the styloid process in human cadavers, with a focus on measuring the length and breadth of the process and examining the spatial orientation of adjacent structures.

The objectives of this study are:

1. To measure the morphometric parameters (length and breadth) of the styloid process in human cadavers and dry skulls.
2. To estimate the prevalence rate of elongated styloid processes in the studied population.
3. To analyze the potential clinical effects of elongated styloid processes by examining the spatial relationships with surrounding neurovascular structures.

Materials and Methods:

This cross-sectional, observational study was conducted on formalin-fixed human cadavers and dry skulls in the Department of Anatomy at a GIMSH, Durgapur. The study sample consisted of 40 formalin-fixed human cadavers and 15 dry skulls, resulting in a total of 110 styloid processes (both right and left sides) for analysis. Styloid processes exhibiting disruption or damage were excluded from the study.

Dissection was performed following the guidelines outlined in Cunningham's Manual to expose the styloid process. Initially, the sternocleidomastoid muscle, a portion of the parotid gland, and the masseter muscle were removed. Subsequently, the ramus of the mandible was exposed and sectioned using a bone cutter to facilitate access to the deeper structures. The styloid process was then carefully dissected and exposed by meticulously removing the surrounding muscles and soft tissues.

To ensure standardized and accurate measurements, two specific points were defined:

1. **Posterior Measure (Length):** This measurement represented the distance from the base of the styloid process, where it originates from the temporal bone, to its distal tip. It was obtained using a digital vernier caliper.
2. **Breadth Measure:** This measurement represented the width of the styloid process at its base. It was also obtained using a digital vernier caliper.

In addition to morphometric measurements, the spatial relationships between the styloid process and the surrounding neurovascular bundle were carefully observed and documented. This involved noting the relative positions of the internal and external carotid arteries, the jugular vein, and cranial nerves IX, X, and XI in relation to the styloid process. Any deviations or variations in these relationships were recorded.

Review of Literature:

The styloid process (SP), a slender bony projection from the temporal bone, has garnered significant attention due to its clinical relevance, particularly in relation to Eagle’s syndrome. This review of literature aims to synthesize existing knowledge on the morphometric analysis of the SP, focusing on cadaveric studies and their implications for clinical practice.

Anatomical Variations and Embryological Origins: The SP originates from the second branchial arch (Reichert's cartilage), and its development involves a complex ossification

process that can result in significant anatomical variations. Studies have documented a wide range of SP lengths and orientations, highlighting the importance of understanding these variations in different populations. Lang and Fischer (1988) provided detailed anatomical descriptions and documented variations in SP length, contributing to foundational knowledge. Embryological studies have further elucidated the developmental processes leading to these variations, emphasizing the potential for anomalies.

Morphometric Studies in Cadavers: Cadaveric studies provide direct access to the SP, allowing for precise morphometric measurements and detailed examination of its relationship with surrounding structures. Several studies have focused on quantifying SP length and breadth, revealing significant inter-individual and population-specific differences. Kazkayasi et al. (2003) conducted a comprehensive morphometric and clinical evaluation of the SP, highlighting the importance of accurate measurements in clinical practice. These studies often utilize digital vernier calipers and other precise measuring tools to ensure accuracy.

Elongated Styloid Process and Eagle's Syndrome: The association between an elongated SP and Eagle's syndrome has been a major focus of research. Eagle (1937, 1948) initially described the syndrome, linking cervicofacial pain and related symptoms to an elongated SP. Subsequent studies have explored the prevalence of elongated SPs in various populations, with significant variations reported. Badhey et al. (2017) provided a comprehensive review of Eagle's syndrome, summarizing its clinical presentation, diagnostic challenges, and management strategies.

Radiological Evaluation and Clinical Correlation: While cadaveric studies offer valuable anatomical insights, radiological imaging plays a crucial role in clinical diagnosis. Multi-detector computed tomography (MDCT) and cone-beam computed tomography (CBCT) have become the gold standards for evaluating SP morphology in vivo. Murtagh et al. (2001) demonstrated the utility of CT findings in diagnosing Eagle's syndrome. Studies have also explored the correlation between radiological measurements and clinical symptoms, highlighting the importance of integrating anatomical and clinical data.

Spatial Relationships and Neurovascular Structures: The close proximity of the SP to vital neurovascular structures underscores its clinical significance. Studies have examined the spatial relationships between the SP and the internal and external carotid arteries, the jugular vein, and cranial nerves IX, X, and XI. These studies have revealed potential mechanisms by which an elongated SP can cause symptoms, such as compression or irritation of these structures. Gossman et al. (1977) explored the functional relationships of the hyoid muscles, which are closely associated with the SP, providing insights into the biomechanical aspects of related symptoms.

Population-Specific Variations: Research has consistently demonstrated significant variations in SP morphology across different populations. Studies have examined SP dimensions in Turkish, Korean, and other populations, revealing ethnic and geographical differences. Ilgüy et al. (2005) investigated the incidence of elongated SPs in a Turkish population. Kim et al. (2009) examined the correlation between elongated styloid process and clinical symptoms in a Korean population. These studies underscore the importance of considering population-specific data in clinical practice.

Clinical Implications and Surgical Considerations: The clinical implications of SP morphology extend beyond Eagle's syndrome. An elongated SP can contribute to various head

and neck pathologies, including temporomandibular joint disorders and neuralgia. Accurate morphometric data is essential for planning surgical interventions and minimizing complications. Keur et al. (1986) discussed the clinical significance of the elongated SP, highlighting its role in various clinical presentations.

Methodological Considerations: Studies have employed various methodologies for measuring SP dimensions, including direct measurements in cadavers and radiological assessments. Methodological variations can contribute to differences in reported findings, emphasizing the importance of standardized measurement techniques. Bland and Altman (1986) provided statistical methods for assessing agreement between different measurement methods, which are relevant to studies comparing cadaveric and radiological data.

In conclusion, the literature highlights the importance of comprehensive morphometric analyses of the SP, particularly in cadaveric studies. These studies provide valuable insights into anatomical variations and their clinical implications, contributing to a better understanding of Eagle's syndrome and related pathologies. Further research is needed to integrate anatomical, radiological, and clinical data to improve diagnostic accuracy and optimize patient management.

Results:

A total of 110 styloid processes were bilaterally measured in this study. Following a thorough review of the literature, a length exceeding 30 mm was defined as elongated. Four styloid processes, found in two cadavers, exhibited lengths greater than 30 mm, resulting in a calculated prevalence rate of 3.6%. The maximum length measured was 45.3 mm, and the minimum length was 5.2 mm. The maximum breadth recorded was 6.7 mm, while the minimum breadth was 1.7 mm. The average length of the styloid process was 16.1 mm on the right side and 16.07 mm on the left side. The average breadth was 5.7 mm on the right side and 5.13 mm on the left side

Observations of Elongated Styloid Processes: In the first variant cadaver (cv1), the tip of the elongated styloid process on the right side was observed to be in close proximity to the facial artery. Notably, a common faciolingual trunk arose from the external carotid artery on the same side, with the facial artery positioned near the elongated styloid process. The origins of the styloid muscles were normal on both the right and left sides of cv1. In the second variant cadaver (cv2), the tips of the elongated styloid processes were bilaterally observed to be in close approximation to the internal carotid arteries. Close approximation of the tips of the elongated styloid processes to the hypoglossal nerve was also noted bilaterally in cv2. The origins of the styloid muscles were normal on both sides of cv2.

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