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Styloid Process Length Variations: An Osteological Study

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Abstract

Objective. The objective of this study was to study the morphometry of the styloid process of the temporal bone and the prevalence of an elongated styloid process in relation to side and gender. **Material and Method.** The present study included 200 human skulls which were procured from the rich osteological collections of the Department of Anatomy, Faculty of Medicine, University of Sarajevo. The styloid process was observed macroscopically on both sides of all the skulls and elongations, if any, were noted. The lengths of the styloid processes were measured using digital vernier calipers. The measurements were taken from the point of emergence of the process (base) up to the tip. **Results.** Out of 200 specimens, only 14 cases (7%) exhibited an elongated styloid process. The mean length of the styloid process was 25.8±4.68 mm and 24.2±4.54 mm for the right and left sides, respectively. The size of the styloid process did not different significantly between the two sides (P=0.724). The mean length of the styloid process was 24.05±3.54 mm in females and 25.95±5.68 mm in males, and the difference was statistically significant (P=0.023). **Conclusion.** The study and knowledge of the anatomical variations of the styloid process in the Bosnian population may help clinicians to diagnose Eagle's syndrome. Knowledge of this disorder can prevent the worsening of the painful symptoms related to an elongated styloid process.

Key Words: Elongated Styloid Process ▪ Anatomic Variation ▪ Eagle's Syndrome.

Introduction

The styloid process is a thin and sharp bone structure, protruding downward and forward from the underside of the temporal bone. It is situated between the internal and external carotid arteries, posterior to the pharynx, which covers the stylohyoid, styloglossus and stylopharyngeal muscles (1). It has embryonic origin in the Reichert's cartilage of the second arch, together with the stylohyoid ligament and the lesser horn of the hyoid bone forms the stylohyoid complex or stylohyoid apparatus (2). In the adult, the stylohyoid ligament, which is normally composed of dense fibrous connective tissue, may retain some of its embryonic cartilage and thus have the potential to become partially or completely ossified. If these structures solidify, they can cause the pain and suffering present in Eagle's syndrome (3).

Steinmann proposed various theories to explain ossification. These were: "The theory of reactive hyperplasia" - trauma can cause ossification at the end of the styloid process down the length of the styloid ligament, since the styloid ligament contains remnants of its connective tissue and fibrocartilaginous origins, the potential for ossification remains; "The theory of reactive metaplasia"- an abnormal post -traumatic healing response which initiates the calcification of stylohyoid ligament; and "The theory of anatomic variance" - the early elongation of the styloid process and ossification of the styloid ligament are anatomical variations that occur without recognisable trauma (4).

The normal length of the styloid process is between 25 and 30 mm, and may vary from person to person and even between the two sides of the same individual. When processes exceed this average the term "elongation" is used (5). The elongation of the styloid process is considered an anomaly which may be accompanied by calcification of the stylohyoid and stylomandibular ligaments, and this may trigger a series of symptoms such as: dysphagia, odynophagia, facial pain, ear pain, headache, tinnitus and trismus. This set of symptoms associated with an elongated styloid process is called Eagle's syndrome (6).

The first mention of the pain syndrome associated with an elongated styloid process referred to as "stylalgia" dates back to 1937, when it was described by the American otorhinolaryngologist, Watt Weems Eagle (7). In recent literature, Eagle's syndrome has also been called stylohyoid syndrome, styloid syndrome, elongated process syndrome, stylalgia, styloid–stylohyoid syndrome, styloid dysphagia, chronic styloid angina, temporal rheumatic styloiditis, stylocarotid syndrome or Garel–Bernfeld syndrome (8). Over the last decade, experts have shown a lively interest in the issue of the relationship between the elongated styloid process and various symptoms. A number of scientific papers concerning Eagle´s syndrome or elongated styloid process were published between 2000 and 2020.

On the one hand, interest in this phenomenon is surely the result of the enormous technological developments in medical imaging in the field of radiology. Nowadays, the diagnosis of the elongated styloid process is established by three-dimensional computed tomography (9) or cone beam computed tomography (10), which provide more precise topographic-anatomical and morphometric descriptions of this anatomical anomaly, compared to panoramic radiographs (11). Considering the dynamic alteration of the anatomical relationship between the elongated styloid process and surrounding nerves and vessels relative to head position, Siniscalchi recommended that both magnetic resonance imaging (MRI) and ultrasonography of the head and neck region should be performed with the head in different positions (rest position, maximum extension, maximum flexion of the head, and maximum right and maximum left rotation) (12).

On the other hand, interest in the issue of an elongated styloid process is growing among surgical experts due to expanding options in terms of surgical approaches to the resection of this anatomical anomaly. To this day, no standardized treatment algorithm for an elongated styloid process has been established, although various surgical approaches have been described. Even though the traditional approaches (transcervical or transoral styloidectomy) are still in practice, novel modalities, such as transoral robotic surgery, have been employed lately in selected patients, to avoid the potential shortcomings associated with other approaches (13).

Finally, yet importantly, it is necessary to emphasize perhaps the most significant factor in the "rise of popularity" of Eagle´s syndrome — the newly described neurological symptomatology possibly associated with an elongated styloid process. This may be a causative factor in the development of internal carotid artery compression (14), significant compression of the internal jugular vein (15, 16), stylocarotid syndrome due to mechanical irritation of the sympathetic plexus in the cervical internal carotid artery (17), or stroke due to carotid artery dissection (18, 19). These recently described neurological morbidities, possibly caused by an elongated styloid process, have a tendency to spark the interest of many other scientists, a phenomenon known as the "snowball effect"—one study builds upon the previous one. Therefore, the number of papers pointing to the importance of this anatomical variation in the pathogenesis of various conditions is growing exponentially, which in turn further enhances the substantial attractiveness of the topic, yielding high numbers of citations.

The aim of this study was to determine the frequency of styloid process elongation in a sample of the Bosnian population.

Materials and Methods

Two hundred skulls from the collection of the Department of Anatomy, Faculty of Medicine,

University of Sarajevo, were used in the present study. Of this number, 109 (54.5%) were male and 91 (45.5%) were female skulls. The ages ranged between 23 and 91 years, with a mean of 57 years (±18.24 standard deviation) for males, and between 19 and 84 years, with a mean of 51.5 years (±16.62 standard deviation) for females.

The distances between the bases and tips of the styloid processes were measured with the help of digital vernier calipers. All the measurements were performed by the authors. The apparent length of the styloid process was measured from the point of emergence of the process to its tip, regardless of whether or not the styloid process was segmented. All measurement was carried out in accordance with the Declaration of Helsinki from 1975 and its amendments from 1983.

Statistical Analysis

The 'Paired Samples *t*-test' was used to evaluate the mean differences between the measured parameters between the right and left sides. A comparison was performed between the right and left sides, and males and females, regarding the symmetrical structures, and $P<0.05$ was considered statistically significant. Statistical analysis was performed using the statistical package IBM Statistics SPSS V19.0. Mean values, standard deviation and the range were all taken into consideration in the statistical analysis.

Results

The morphometric data on the styloid process obtained in the present study is presented in Table 1. Statistical processing of the presented results showed that there is no statistically significant difference in the length of the styloid process in relation to the side ($P=0.724$), but a statistically significant difference was noted in the length of the styloid process in relation to gender ($P=0.023$).

An elongated styloid process was found in the examined material in 7% of cases. There were 5 skulls with a styloid process over 30 mm on the right side (4.6%) and 7 (6.4%) on the left side, in males (Figure 1).

There was only 1 (1.1%) skull with styloid processes over 30 mm in a female (1 on the right, and 1 on the left), (Figure 2).

Figure 1. Elongated styloid process on the right side of a male skull, lateral view (right - 46.61 mm).

Table 1. Measurement of the Styloid Processes

Styloid processes	Gender				P*
	Male		Female		
	Range	Mean±SD	Range	Mean±SD	
Right side (mm)	19.51-46.61	27.1±5.59	16.46-40.96	24.5±3.76	0.724
Left side (mm)	17.00-38.00	24.8±5.76	15.58-39.18	23.6±3.32	
P*	0.023				

SD=Standard deviation; *Paired Samples *t*-test.

Figure 2. Elongated styloid processes on both sides of a female skull, posterior view (right 40.96 mm, left 39.18 mm).

Discussion

The styloid process is part of the stylohyoid complex, along with the lesser cornua of the hyoid bone and the stylohyoid ligament. Excessive or abnormal ossification of the stylohyoid complex components during development may result in an abnormally elongated or angulated styloid process (20, 21). The length of the styloid process was studied by Wang et al., Basekim et al., Savranlar et al., and Jung et al., using radiography and three-dimensional computed tomography (22-25).

According to the literature, the normal length of the styloid process is between 20-30 mm, but it can vary from person to person and even between the two sides of the same individual (26). There is no consensus among researchers as to which length of styloid process should be called elongated. Jung et al. suggested that the styloid process should be considered to be elongated when its length exceeds 45 mm, (24). Keur et al. stated that if the length of the process or the mineralised part of ligaments which appeared on radiography was 30 mm or more, this could be considered an elongated styloid process (4). These different results may be due to the use of different methods for measuring the styloid process. Some authors suggest that measuring the styloid process using plain bones gives the best results compared to radiographs, but data on the osteometric values of the styloid process are scanty. Previous research has shown that the length of the styloid process varies significantly between different populations, ethnic groups and geographical origin.

Our study, based on morphometric analysis of styloid processes in Bosnian skulls, showed that there was no statistically significant difference in the length of the processes on the right and left sides (P=0.724). The average length of the styloid process recorded on the right side was 25.8 ± 4.68 mm, and 24.2±4.54 mm on the left side. Similar values were noted in the studies by Andreade et al., Ramadan et al., and Gozil et al. (27-29).

A statistically significant difference was recorded in our work after processing the data on the length of the styloid process in male and female skulls (P=0.023). Higher values were recorded in male compared to female skulls (25.95±5.68 mm versus 24.02±4.54 mm). Confirmation of these results was found in previous studies (25, 29, 30), although this data contradicts the data that Eagel's syndrome is more common in women.

Elongated styloid continuation was noted in the present paper in 7% of cases, more often on the left side than on the right side. This is similar to what Kaufmans noted in his research (31). Some other researchers have reported a significantly higher incidence of elongated styloid process, such as Monsuor et al., who recorded this phenomenon in as many as 21% of cases (5).

The scarce literature data on the length of the styloid process in the Bosnian population, the incidence of prolonged styloid process, the incidence of Eagel's syndrome, and other data give rise to the need for a much more extensive study than this. We hope that this paper will be an incentive for future researchers to make extensive clinical studies that would provide answers to the questions posed above.

Conclusion

The study and knowledge of the anatomical variations of the styloid process in a population may help clinicians to diagnose Eagle's syndrome. Knowledge of this disorder can prevent the worsening of the painful symptoms related to an elongated styloid process. We believe that this study provides additional information about the frequency of an elongated styloid process in the Bosnian population. Therefore, we consider it important to perform a careful analysis of the angulation of the styloid process and its relationship to adjacent anatomical structures through imaging studies.

What Is Already Known on This Topic:
The styloid process is a thin and sharp bone structure, protruding downward and forward from the underside of the temporal bone. It is situated between the internal and external carotid arteries, posterior to the pharynx, which covers the stylohyoid, styloglossus and stylopharyngeal muscles. The normal length is between 25 and 30mm, and it can vary from person to person, and even between the two sides of the same individual. The elongation of the styloid process is considered an anomaly which may be accompanied by calcification of the stylohyoid and stylomandibular ligaments, and this may trigger a series of symptoms such as dysphagia, odynophagia, facial pain, ear pain, headache, tinnitus and trismus. This set of symptoms associated with an elongated styloid process is called Eagle's syndrome.

What This Study Adds:
We believe that this study provides additional information about the frequency of elongated styloid processes in the Bosnian population. The knowledge of anomalies of the styloid process may be beneficial to otorhinolaryngological surgeons (ENT surgeons), neurologists, and radiologists in daily clinical practice for proper diagnosis and treatment of Eagle's syndrome.

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Conflict of Interest: The authors declare that they have no conflict of interest.

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