

A computed tomography-based morphometric study of the styloid process

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Background: The styloid process (SP) refers to a cylindrical piece projecting from the inferior of the temporal bone, situated anterior to the stylomastoid foramen. It is an anatomic formation close to major vessels and nerves, and its excessive elongation results in pathologies leading to anatomical disorders, such as Eagle's syndrome. Several studies have been conducted on SP in relation to its close proximity to vessels and nerves, but there is no study that reveals its distance to important anatomical formations, such as the internal auditory meatus (IAM), carotid canal (CC), cochlea, tegmen tympani (TT) and tragus. In the current study, we aimed to investigate the incidence of Eagle's syndrome based on morphometric measurements of SP.

Materials and methods: The patient files archived in the Radiology Department of Adiyaman University Training and Research Hospital were retrospectively examined. The study was carried out on the data of patients for whom specialist radiologists found no pathology findings on the computed tomography images. A total of 77 individuals (36 females and 41 males) aged 22 to 54 years were included in the study. The length of SP and its distances to IAM, cochlea, CC, TT and tragus were obtained using computed tomography radiological measurements.

Results: When the individual measurements performed on computed tomography images were evaluated in men and women, no significant difference was found concerning the distance between SP and various anatomic structures in close proximity to SP ($p > 0.05$). However, there was a statistically significant difference between the genders in length of the right SP ($p = 0.003$) and left SP ($p = 0.006$).

Conclusions: This anthropometric study revealed the standard morphometric measurements of SP. We believe that the data obtained will help clinicians to identify and diagnose pathologies more easily. (Folia Morphol 2020; 79, 1: 120–126)

Key words: temporal bone, styloid process, morphometric measurements, computed tomography

INTRODUCTION

The temporal bone is a complex structure located in the temporal region, including organs related to hearing and balance. It consists of three parts: petromastoid, squamous, and tympanic [1]. The styloid

process (SP) is a cylindrical piece projecting from the inferior surface of the petrous part of the temporal bone, situated anterior to the stylomastoid foramen between the internal and external carotid arteries and the pharyngeal wall [2]. Being located in the temporal

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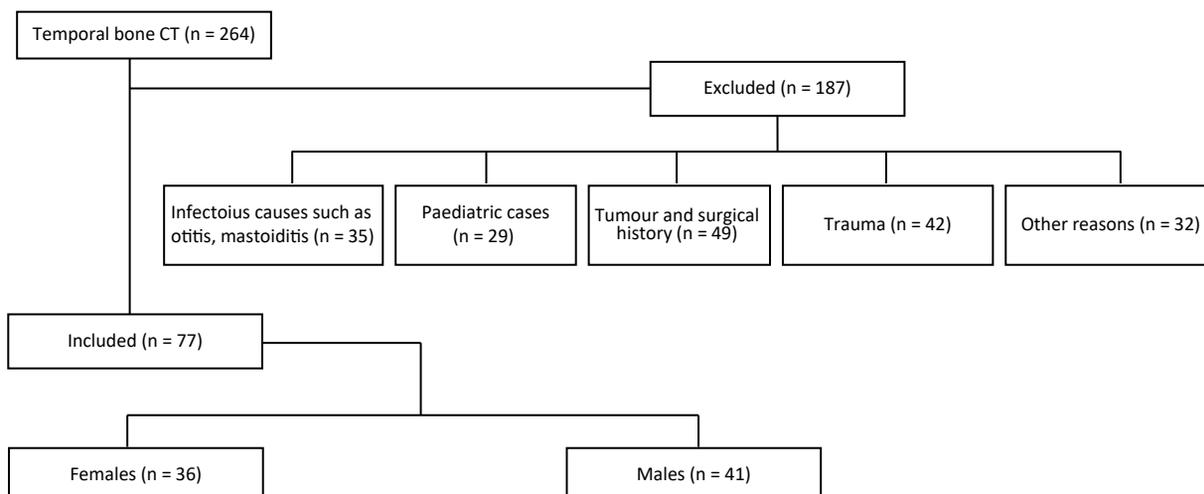


Figure 1. Consort flow diagram; CT — computed tomography.

bone, SP is a clinically important anatomical entity due to pathologies caused by changes in its length [24].

Excessive elongation of this structure, which has close proximity to important vessels and nerves, results in pathologies that cause anatomical disorders [22]. The normal length between the SP base and the apex is 25 mm, and a measurement of 30 mm or greater is considered to indicate elongation of SP and called Eagle's syndrome, which causes pain, dysphagia, glossopharyngeal and neurological symptoms [18, 23]. In clinical practice, in the evaluation of pathological changes related to diseases, it is necessary to have knowledge of the normal anatomy of the structure in question and standardise morphometric measurements of its distance to the surrounding formations. Several studies have been conducted on SP focusing on its close proximity to the vessels and nerves, but to the best of our knowledge, there is no study revealing its distance to important anatomical formations, such as the internal auditory meatus (IAM), carotid canal (CC), cochlea, tegmen tympani (TT), and tragus [6, 26, 27]. Such measurements are important for determining normal values in clinical cases characterised by vertigo, tinnitus, chewing problems, and pain.

In the current study, morphometric measurements of SP were undertaken to clarify the mean SP length, and the distance of SP to neighbouring anatomical structures, as well as their relationship were determined. The data obtained from the study is expected to assist physicians in diagnosing cases presenting with symptoms disrupting their quality of life, such as vertigo, tinnitus, chewing problems, and pain.

MATERIALS AND METHODS

In this study, the patient files obtained from the archives of the Radiology Department of Adiyaman University Training and Research Hospital were retrospectively examined. A total of 77 patients, 36 women and 41 men (age range: 22–54 years), who underwent computed tomography (CT) of the temporal bone between June 2018 and January 2019 were included in the study. The radiological images were re-evaluated by a radiologist with more than 10 years of experience. The cases with poor CT image quality or a history of head and neck surgery, as well as those that underwent temporal bone CT for trauma and tumour were excluded. Incidents that do not concern temporal bone structures, such as sinusitis and adenoid hypertrophy were disregarded (Fig. 1).

CT protocol and imaging analysis

In all cases, CT was performed using a Toshiba Aquilion 64 system (ToshibaMedical, Tochigi, Japan). The CT scans were continuously obtained in the axial plane, parallel to the infraorbitomeatal line, covering the area from the arcuate protrusion in the upper part to the mastoid apex in the lower part (FOV: 22 cm, thickness: 0.5 mm, kV: 120, mAs: 200, effective mAs: 150). The radiological images were evaluated in the coronal plane using a dedicated workstation. Multi-planar and three-dimensional (3D) images were used where necessary (Fig. 2). The measurements were undertaken and recorded in millimetres.

The root length of SP was accepted as the tympanic part of the temporal bone. The mediolateral

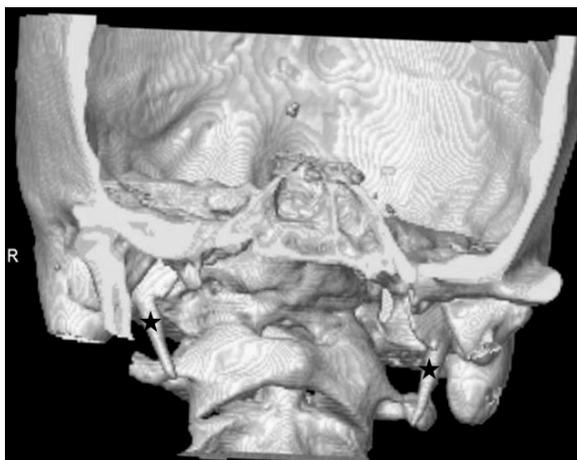


Figure 2. A three-dimensional computed tomography image of the styloid process (asterisk).

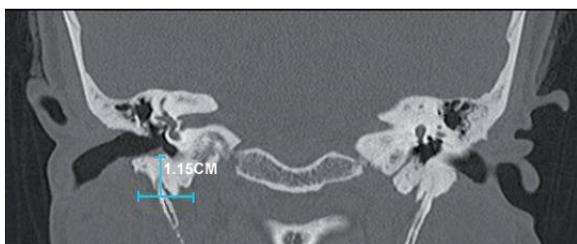


Figure 3. Measurement of the root length of the styloid process.



Figure 4. Measurement of the distance between the styloid process and the internal auditory meatus.

line passing through the lower border of the SP root in the coronal plane, parallel to the scanning plane, was taken as the reference point. Performing measurements on this reference line, the distances of SP to IAM, CC, cochlea, TT and tragus were noted. In addition, the total length of SP measured on 3D and/or maximum intensity projection images was recorded (Figs. 3–10).

Statistical analysis

Statistical analyses were performed using SPSS 15.0 programme after transferring the data obtained from radiological images to a computer environment.

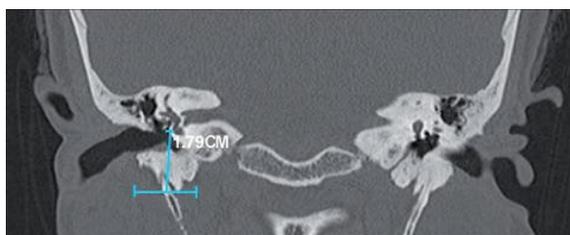


Figure 5. Measurement of the distance between the styloid process and the cochlea.

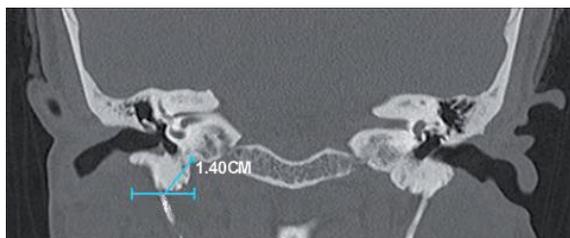


Figure 6. Measurement of the distance between the styloid process and the carotid canal.



Figure 7. Measurement of the distance between the styloid process and the tegmen tympani.

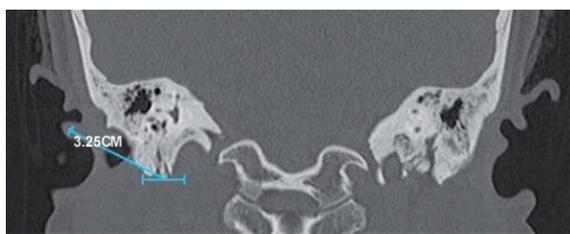


Figure 8. Measurement of the distance between the styloid process and the tragus.

The suitability of the data for normal distribution was evaluated by the single-sample Kolmogorov-Smirnov test. Levene statistics were used for the homogeneity analysis of group variances. The independent-samples t-test was conducted to determine the differences between male and female biometric measurements, and the paired-samples t-test was utilised to determine the differences between the left and right measurements of men and women. The results were obtained

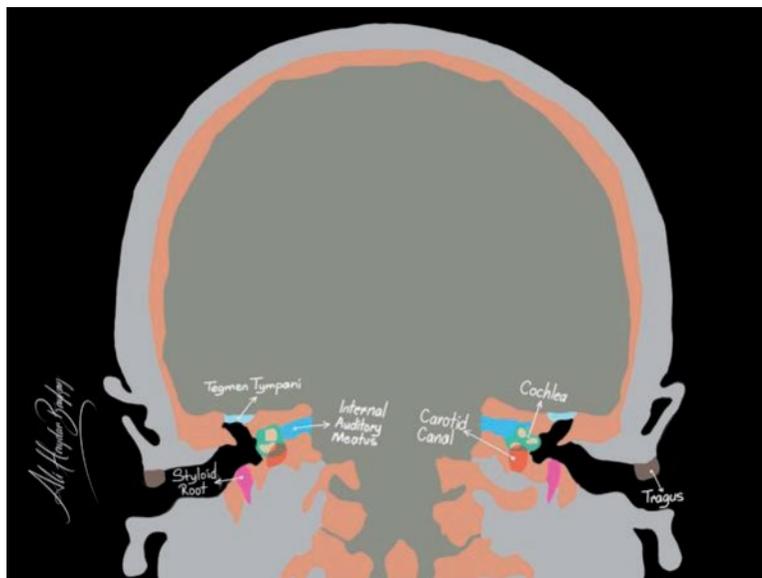


Figure 9. Illustration of styloid process and adjacent anatomical structures on the coronal plane.

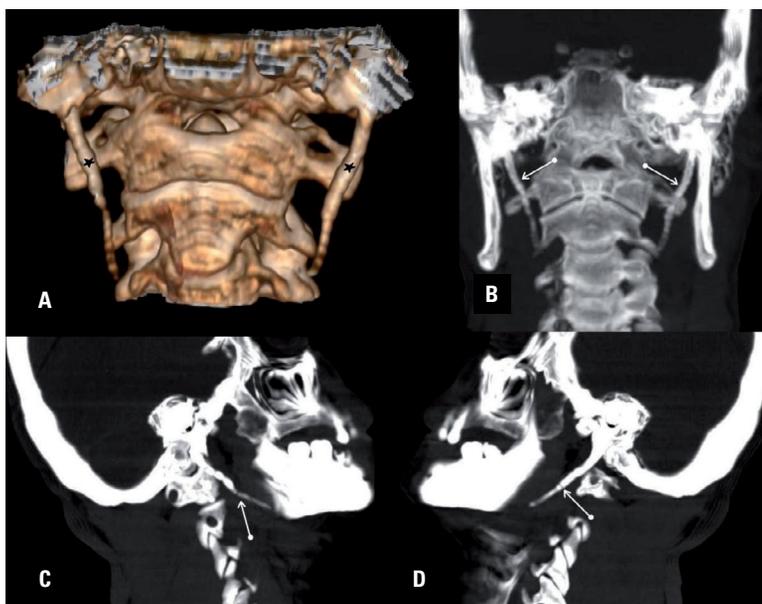


Figure 10. Radiological images of a patient with Eagle syndrome. In the three-dimensional image (A) both styloid process (asterisk) go down to the level of the third cervical vertebra transfer processes. Coronal (B) and sagittal (C, D) computed tomography images show elongated styloid process (arrows).

as mean \pm standard deviation (SD). The significance level was accepted as $p < 0.05$.

RESULTS

The mean age was 39.00 ± 10.76 years for 36 female participants and 34.85 ± 8.19 years for 41 male participants. The mean lengths of the right and left SP were found to be 30.11 mm and 29.12 mm, respectively in women, and 30.30 mm and 29.36 mm,

respectively in men. SP was measured more than 30 mm in 7 of the women, bilateral in 5 and unilateral in 2 (1 right and 1 left). In males, SP was measured to be longer than 30 mm reference value in a total of 9 cases, seven of whom were bilateral and 2 were unilateral (right side). Eagle syndrome was reported to be 19.4% and 21.9% in women and men, respectively. When all women and men were evaluated together, the prevalence of eagle syndrome was 20.7%.

Table 1. Gender-based intragroup comparison of the styloid process (SP) measurements

Gender			N	Mean	SD	P	
Female	Pair 1	RRL	36	10.82	0.78	0.679	
		LRL	36	10.76	0.88		
	Pair 2	R IAM	36	19.56	1.18		0.742
		L IAM	36	19.63	1.31		
	Pair 3	R Cochlea	36	16.08	1.45		0.744
		L Cochlea	36	16.01	1.38		
	Pair 4	R CC	36	15.04	1.14		0.682
		L CC	36	15.18	2.09		
	Pair 5	R TT	36	27.67	1.83		0.854
		L TT	36	27.61	2.11		
	Pair 6	R Tragus	36	34.71	2.04		0.761
		L Tragus	36	34.81	2.08		
	Pair 7	R SP length	36	30.11	6.81		0.542
		L SP length	36	29.12	6.46		
Male	Pair 1	RRL	41	11.51	1.13	0.663	
		LRL	41	11.45	1.19		
	Pair 2	R IAM	41	20.27	1.55		0.325
		L IAM	41	20.05	1.49		
	Pair 3	R Cochlea	41	16.85	1.79		0.635
		L Cochlea	41	16.76	1.40		
	Pair 4	R CC	41	16.10	1.45		0.354
		L CC	41	15.93	1.26		
	Pair 5	R TT	41	27.72	2.42		0.248
		L TT	41	27.45	1.97		
	Pair 6	R Tragus	41	35.78	1.70		0.037
		L Tragus	41	36.24	1.75		
	Pair 7	R SP length	33	30.30	7.44		0.413
		L SP length	33	29.36	8.42		

CC — canalis caroticus; L — left; LRL — left root of SP; IAM — internal auditory meatus; R — right; RRL — right root length of SP; SD — standard deviation; TT — tegmen tympani

In CT measurements performed individually for the women and men, the lengths of the right and left SP and the distance of SP to the surrounding tissues were determined (Figs. 3–10). When the measurements were statistically evaluated, there was no difference within the groups in the gender-based comparison of the distance between SP and various neighbouring anatomical formations ($p > 0.05$) (Table 1). However, according to the gender-based intergroup comparisons, there were statistically significant differences in the root length of the right ($p = 0.003$) and left ($p = 0.006$) SP (Table 2).

There was a significant difference between men and women concerning the distance of SP to the right

Table 2. Gender-based intergroup comparison of the styloid process (SP) measurements

	Gender	N	Mean	SD	P
RRL	Female	36	10.82	0.78	0.003
	Male	41	11.51	1.13	
LRL	Female	36	10.76	0.88	0.006
	Male	41	11.45	1.19	
R IAM	Female	36	19.56	1.18	0.027
	Male	41	20.27	1.55	
L IAM	Female	36	19.63	1.31	0.192
	Male	41	20.05	1.49	
R Cochlea	Female	36	16.08	1.45	0.043
	Male	41	16.85	1.79	
L Cochlea	Female	36	16.01	1.38	0.021
	Male	41	16.76	1.40	
R CC	Female	36	15.04	1.14	0.001
	Male	41	16.10	1.45	
L CC	Female	36	15.18	2.09	0.058
	Male	41	15.93	1.26	
R TT	Female	36	27.67	1.83	0.915
	Male	41	27.72	2.42	
L TT	Female	36	27.61	2.11	0.732
	Male	41	27.45	1.97	
R Tragus	Female	36	34.71	2.04	0.014
	Male	41	35.78	1.70	
L Tragus	Female	36	34.81	2.08	0.002
	Male	41	36.24	1.75	
R SP length	Female	36	30.11	6.81	0.911
	Male	33	30.30	7.44	
L SP length	Female	36	29.12	6.46	0.894
	Male	33	29.36	8.42	

CC — canalis caroticus; L — left; LRL — left root of SP; IAM — internal auditory meatus; R — right; RRL — right root length of SP; SD — standard deviation; TT — tegmen tympani

IAM ($p = 0.027$), but no significant difference was found in the distance of SP to the left IAM (Table 2). According to the gender-based intergroup comparisons, the distances of SP to the right ($p = 0.043$) and left ($p = 0.021$) cochleae were significant. Similarly, the distances of SP to the right ($p = 0.001$) and left ($p = 0.058$) CC provided significant results (Table 2).

DISCUSSION

Styloid process, which is part of the temporal bone, is an important anatomical formation that provides attachment points for muscles and ligaments [24]. SP is important for both medical doctors and

dentists due to its proximity to many important anatomical structures in this part of the body.

In studies investigating SP length, the normal length of SP was reported as 25 to 30 mm by Eagle [7], less than 30 mm by Kaufman et al. [11], and 15.2 mm by Moffat et al. [17]. When the current literature is examined, it is observed that the length of SP varies from 15 to 47 mm, and values above 30 mm are considered to indicate elongation of SP, which is known as Eagle's syndrome [6]. According to our study data, the mean SP length was 29 mm in women and it approached 30 mm in men. The length of SP can vary greatly with differences being observed even in the same individual between the right and left sides.

In the literature, elongated SP (Eagle syndrome) frequency is highly variable and reported between 1.4% and 83.6%; however, radiographic incidence is between 2% and 32% [13]. Several studies investigating the prevalence of Eagle syndrome in Turkish population have been reported between 1.1% and 7.7% [9]. In this study, this rate has been found higher (20.7%).

Studies present different results concerning the relationship between the SP length and gender [3, 14, 21, 25]. For example, Nalçacı et al. [20] found no significant difference between the SP length and gender, but according to our measurements, the gender-based differences in the right and left SP lengths were significant. We believe that the significantly longer SP in males is due to the anatomical variations related to gender. In addition, the distances of SP to some of the neighbouring structures were also observed to significantly differ between the right- and left-side measurements. This suggests that in addition to the gender-based differences in anatomical structures, it is possible to observe variations in the different anatomical regions of the same person. Therefore, we consider that gender-based and right-left differences should be considered in clinical approaches.

There are many morphometric and anthropometric studies related to SP [6, 10, 12, 16, 18, 22, 23, 26, 27]. Most studies in the literature focus on calcification of elongated SP and the pathology caused by elongated SP, known as Eagle's syndrome [3, 10, 12, 14, 16, 18, 20, 21, 23, 25]. Therefore, the data obtained from our study may constitute a reference source revealing the distances between SP and neighbouring anatomic formations.

The distance between SP and the cochlea was 16 mm in females and males, while the SP-CC distance

significantly differed between genders, being measured as 15 mm and 16 mm, respectively. The mean SP-TT distance was 17 mm, and the SP-tragus distance ranged from 34 to 36 mm. With these measurements, the distances of SP to the neighbouring structures were determined as reference values for the Turkish population. Our review of the literature did not show any such radiological data. Thus, we consider this as a fundamental study that radiologically reveals the morphometry of SP, a structure that causes various pathologies in medicine and dentistry, in relation to its neighbouring structures.

We believe that SP-related factors can also cause pathologies characterised by vertigo, tinnitus, chewing problems, and pain. When the literature is examined in detail, regional pain due to calcification of the stylohyoid ligament is seen [4]. Cranial nerve and carotid artery compression due to anatomical changes in this region are known as causes of vertigo [5, 15, 19]. The SP-CC distance obtained from this study and gender-based measurements provide normal values that can be used as reference in identifying possible pathologies. It has previously been reported that SP-related differentiations can lead to the compression of the cranial nerve, resulting in facial pain, dysphagia, foreign body sensation, hyper salivation, tinnitus, and otalgia during head rotation [8].

Diagnosis and treatment are of great importance in the elimination of above-mentioned complaints that disrupt the ergonomics of life. We believe that the normal values of SP in different populations should be clarified in order to eliminate SP-related anatomical defects. This will make it easier to identify pathologies and prevent possible defects through pre-operative planning and various medical treatments. Knowing the length of the SP and its distance to adjacent anatomic structures may shed light on prior planning in surgical procedures of these locations (such as head and neck and dental surgery), avoiding potential complications such as carotid artery injuries. We also hope that the radiological demonstration of these complex anatomical structures in the neighbourhood of SP will make it easier for anatomy students to understand.

This study has certain limitations. The first one concerns the retrospective design and it also includes the small sample size. The second one is that clinical and laboratory data leading to the consideration that cases were healthy was only accessed through the archives.

CONCLUSIONS

In this study, the relationship of certain parts of the temporal bone with SP and standard morphometric measurements of SP were determined based on CT data. Knowing the radiological measurements of SP and its relationship with other formations on the temporal bone can be a radiological and anatomical guide for the diagnosis or monitoring of health problems that impair the quality of life, such as tinnitus, vertigo, chewing problems, and especially Eagle's syndrome.

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