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HEAD AND NECK

Morphometric examination of the styloid process by 3D-CT in patients with Eagle syndrome

Veysel Atilla Ayyildiz[1] · **Fatih Ahmet Senel**[2] · **Ahmet Dursun**[3] · **Kenan Ozturk**[3]

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Abstract

Purpose This study aimed to obtain the length, medial-anterior angulation and basis-apex coordinates of the styloid process in patients with Eagle syndrome by three-dimensional computed tomography.

Methods This study was performed on three-dimensional computed tomography images obtained from the hospital picture archiving and communication system (by obtaining 3D images by a RadiAnt DICOM viewer 4.6.9 version). In this study, the anterior and lateral lengths of the styloid process, its anterior and medial angulation, and the coordinate values on the x, y, and z-axes of 24 patients (14 males, 10 females) diagnosed with Eagle syndrome were examined.

Results The mean anterior lengths were found to be 41.45 mm on the right and 36.07 mm on the left sides, while the mean lateral lengths were found to be 42.15 mm on the right and 37.59 mm on the left sides. The mean medial angulation was measured to be 62.91° on the right and 63.42° on the left, while mean anterior angulation was measured to be 28.01° on the right and 30.43° on the left. The styloid process basis coordinates were determined as (right: $x=-41.30$, $y=0$, $z=0$, left: $x=40.79$, $y=0$, $z=0$), and apex coordinates were determined as (right: $x=-22.61$, $y=-36.86$, $z=-19.52$, left: $x=24.90$, $y=-32.14$, $z=-18.65$).

Conclusion Knowing the styloid process basis and apex coordinates in addition to knowing the its length and angulation will be useful in diagnosing Eagle syndrome. We think that these results in relation to the coordinates of the styloid process will bring a new perspective to clinicians who investigate the length and angulation of the styloid process.

Keywords Styloid process · Angulation · Computed tomography · Coordinate · Matlab

Introduction

The styloid process (SP) is a thin needle-like protrusion, which is derived from the second branchial arch from the proximal surface of Reichert's cartilage, is located on the anterior side of the foramen stylomastoideum, emerges from the lower surface of the pars petrosa of the temporal bone and extends downward-forward [1, 2].

The SP is ossified until 5–8 years of age and continues to grow. The elongation of the SP slows down at about 30 years of age [3]. Eagle determined the normal length of the SP between its basis and apex as 25 mm, evaluated 30 mm and more as elongated and reported that it might cause Eagle syndrome [4]. Eagle syndrome is an important clinical condition for otolaryngologists [5].

In many studies conducted to investigate the incidence of elongated SP, 4% of the patients were reported to have the elongated SP. 4–10.3% of these patients were reported to be symptomatic [6]. When the SP is elongated, it may trigger symptoms such as a sense of a foreign body in the throat, pain while moving the head, vertigo, dysphagia, otalgia, facial pain, headache, tinnitus, and trismus by creating pressure on the neighboring neurovascular structures [2].

To evaluate the length of the SP, imaging methods such as panoramic radiography [2, 7], cone-beam computed

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✉ Kenan Ozturk
kenanozt@hotmail.com

1 Department of Radiology, Faculty of Medicine, Suleyman Demirel University, 32260 Isparta, Turkey

2 Department of Computer Engineering, Engineering Faculty, Suleyman Demirel University, 32260 Isparta, Turkey

3 Department of Anatomy, Faculty of Medicine, Suleyman Demirel University, 32260 Isparta, Turkey

tomography (CBCT) [8], orthopantomogram (OPG) [9], lateral cephalometric radiography [10], multidetector computed tomography (MDCT) [11] and anatomical methods such as measurements in the dry skull [1, 7] were used.

The SP extends towards the fossa tonsillaris, and its apex is localized between the internal and external carotid arteries. The glossopharyngeal, vagus, accessory, hypoglossal nerves, sympathetic trunk, internal jugular vein, and internal carotid artery are localized in the medial of the SP [2]. The localization of the SP is clinically important due to its association with these neurovascular structures. Therefore, in our study, it was aimed to obtain the lengths, medial and anterior angulations of the SP and especially its basis and apex coordinates not previously found in the literature.

Material and methods

In this study, the morphometric features of the SP of 24 patients (14 males, 10 females) diagnosed with Eagle syndrome and aged between 21 and 92 years (mean age 52.75 ± 18.41) were examined. Of the 24 patients in our study, 12 patients were diagnosed with bilateral, and 12 patients were diagnosed with unilateral (10 on the right side, 2 on the left side) Eagle syndrome. The distribution of clinical symptoms of patients included in our study is given in Table 1.

The CT images of the patients with Eagle syndrome were converted to 3D by "RadiAnt DICOM viewer 4.6.9 version" and the sites to be measured were marked, the screenshot was taken and transferred to the Matlab R2016a software. Then, using the ginput tool of the Matlab, the lengths, angulations, and positions on the coordinate plane of the SP were determined according to a specified reference measurement. The graphics showing the positions of the SP on the coordinate plane were also obtained using the Matlab.

Measurements

1. Styloid process (SP) length: The anterior (Fig. 1) and lateral (Fig. 2) SP lengths were obtained by measuring the right and left side SP lengths separately from the anterior and lateral.
2. Origin point: The point where the vertical axis passing through the midline of the head intersects the axis that combines the bases of the SP was accepted to be the origin point (Fig. 1).
3. Apex coordinates: The coordinates of the SP apexes were determined on the coordinate plane (x, y, z) (Figs. 3a, 4a and 5a).

- x: The one that combines the bases of the SP when viewed from the front was accepted as the transverse axis (Fig. 1).
- y: The one that passes through the midline of the head when viewed from the front was accepted as the vertical axis (Fig. 1).
- z: The one that passes through the junction point of the x and y-axes was accepted as the sagittal axis (Fig. 2).

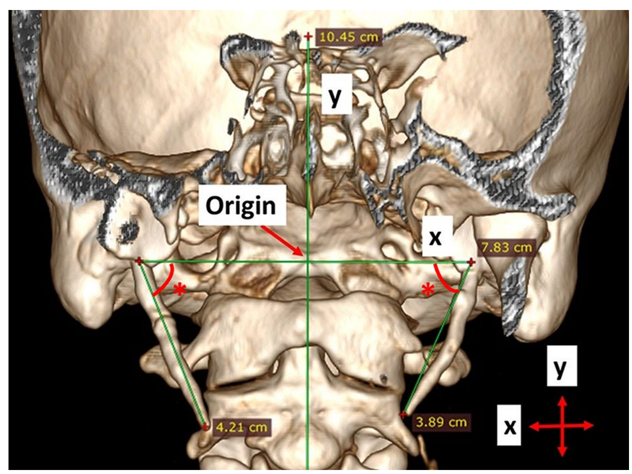

Fig. 1 The SP lengths and the x, y coordinate planes measured from the anterior view. (*) Medial angulation

Table 1 Symptoms of patients with Eagle syndrome

Symptoms	Number of patients ($n=24$)	Styloid process larger than 30 mm
Pain in the neck	11	Bilateral in six patients, right side in four patients, left side in one patient
Throat pain	5	Bilateral in four patients, right in one patient
Foreign body sensation	3	Bilateral in one patient, right side in two patients
Pain on swallowing	2	Right side in one patient, left side in one patient
Otalgia	2	Right side in two patients
Dysphagia	1	Bilateral

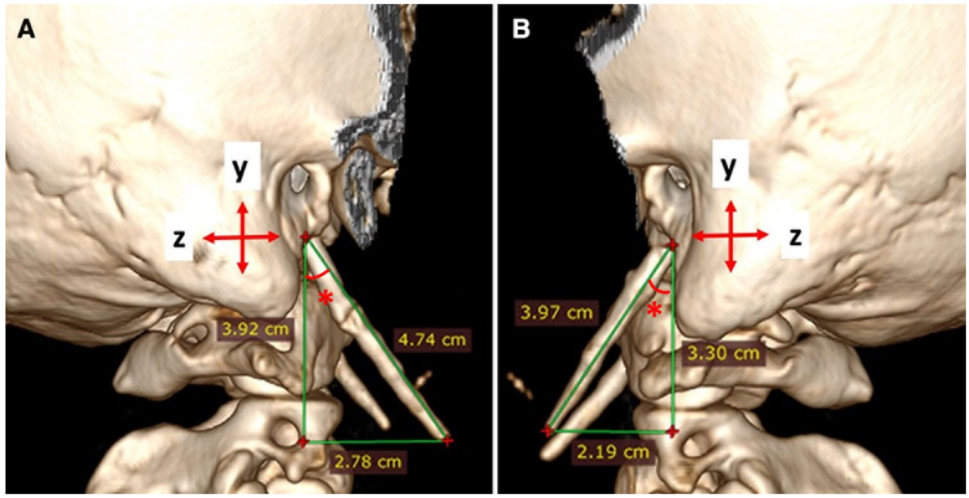

Fig. 2 The SP lengths and the *y*, *z* coordinate planes measured from the lateral (**a** right, **b** left) view. (*) Anterior angulation

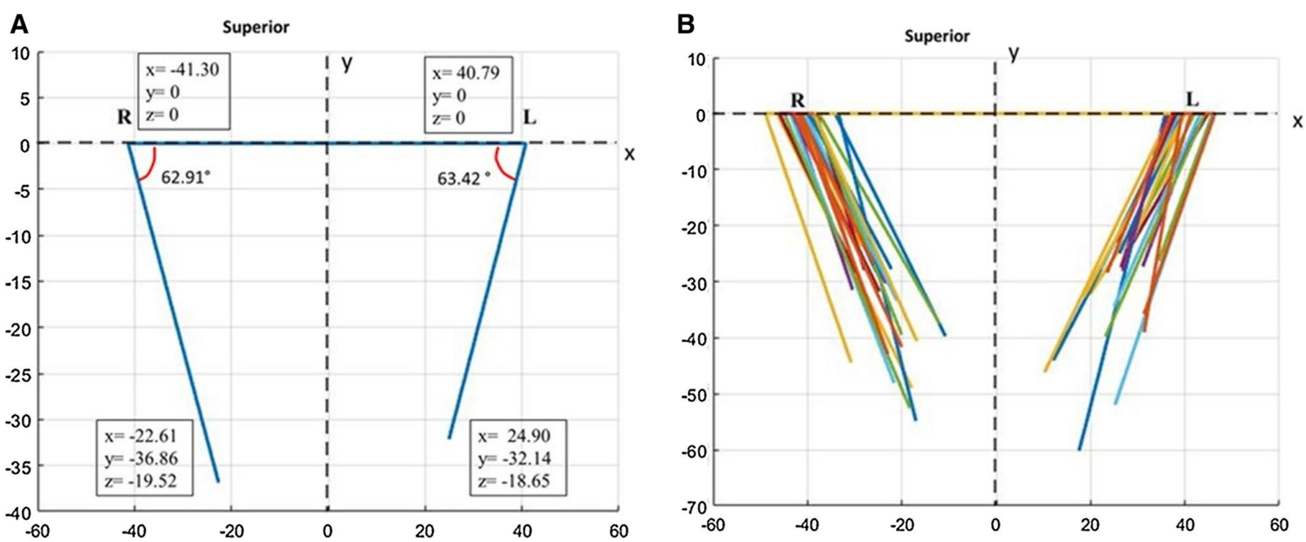

Fig. 3 **a** The mean coordinate values and the mean medial angulations of the base and peak points of the SPs when viewed from the anterior, **b** the anterior views of all SPs

4. Basis coordinates: The distances of the right and left-side SP bases were measured from the origin point.
5. Medial angulation (MA) of the styloid process: The angle between the long axis of the SP and the axis joining the SP bases was measured on the coronal plane (Fig. 1).
6. Anterior angulation (AA) of the styloid process: The angle between the long axis of the SP and the vertical axis passing through the SP basis was measured on the sagittal plane (Fig. 2).

Results

Morphometric data of 24 patients with Eagle syndrome were obtained. The SP length was determined from the anterior and lateral (Table 2). The SP lengths (anterior, lateral) were compared by gender on the right and left sides, and the SP lengths on both sides were higher in males. However, this difference was not statistically significant (Table 2). The mean anterior and lateral SP lengths were

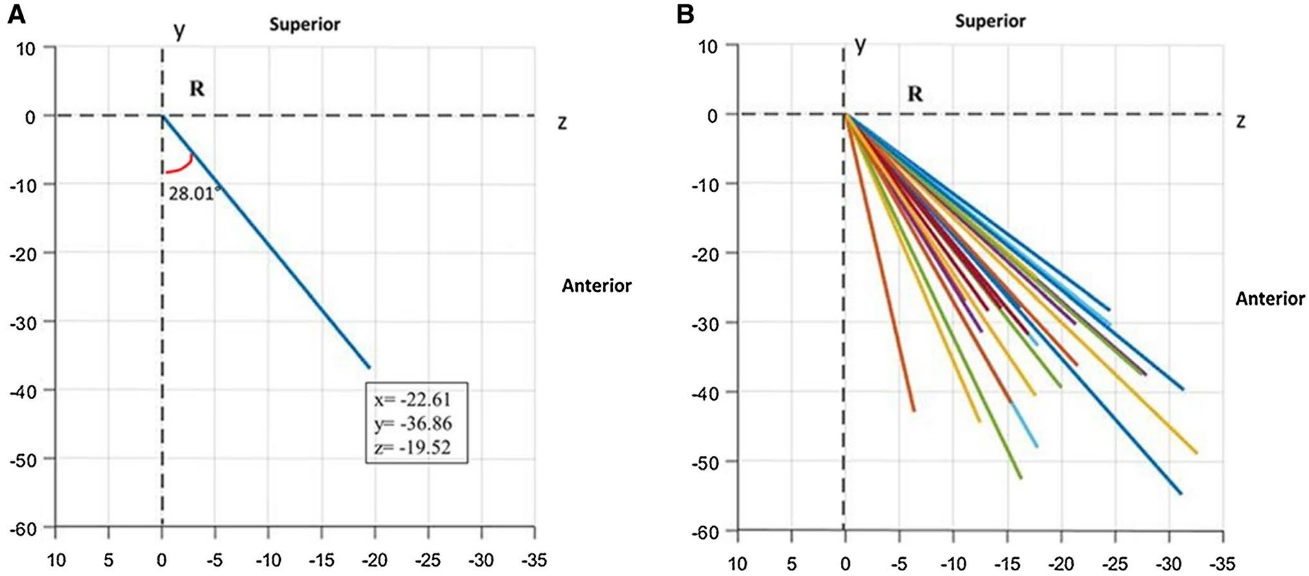

Fig. 4 **a** The mean coordinate values and the mean anterior angulation of the peaks of the SPs when viewed at the right SPs from the lateral, **b** the lateral views of all the right SPs

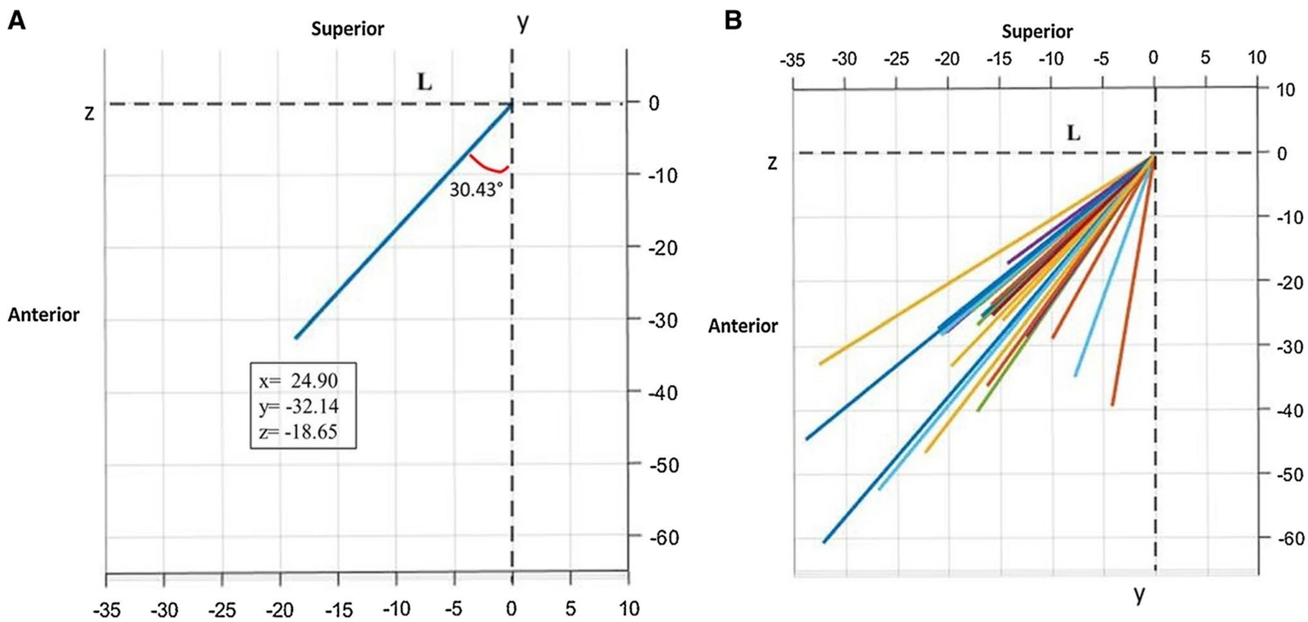

Fig. 5 **a** The mean coordinate values and the mean anterior angulation of the peaks of the SPs when viewed at the left SPs from the lateral, **b** the lateral views of all the left SPs

higher on the right side compared to the left side. However, among them, only the anterior SP length was statistically significantly greater on the right side ($p = 0.023$) (Table 2). The averages of the MA and AA on the right and left sides were determined (Table 2; Figs. 3a, 4a and 5a). The MA and AA were compared by gender on the right and left sides, and while the MA was greater in males on both sides, the AA was found to be greater in females on both sides (Table 2). However, the MA was statistically significantly higher in males on the right side ($p = 0.003$), and the AA was statistically significantly higher in females on the left side ($p = 0.030$) (Table 2). There was no statistically significant difference between the right and left sides of the MA and AA ($p = 0.257$, $p = 0.853$, respectively) (Table 2).

Table 2 Morphometric data on SP length and angulation

	Male ($n=14$) Mean ± standard deviation	Female ($n=10$) Mean ± standard deviation	Total ($n=24$) Mean ± standard deviation	p
SP lengths anterior (mm)				
Right	44.45 ± 10.08	37.25 ± 6.12	41.45 ± 9.23	0.061
Left	38.09 ± 10.94	33.25 ± 10.78	36.07 ± 10.91	0.198
p			0.023*	
SP lengths lateral (mm)				
Right	44.86 ± 9.88	38.36 ± 6.93	42.15 ± 9.20	0.101
Left	39.38 ± 11.65	35.09 ± 10.38	37.59 ± 11.11	0.292
p			0.053	
Medial angulation				
Right	65.13° ± 4.13	59.82° ± 1.88	62.91° ± 4.26	0.003*
Left	65.18° ± 7.14	60.97° ± 3.69	63.42° ± 6.22	0.079
p			0.853	
Anterior angulation				
Right	25.24° ± 8.30	31.87° ± 6.89	28.01° ± 8.29	0.061
Left	27.79° ± 9.72	34.12° ± 6.49	30.43° ± 8.95	0.030*
p			0.257	

SP styloid process

*$p<0.05$

Table 3 Coordinate values of basis and apex of SP

	Positions in the coordinate plane		
	x	y	z
SP basis			
Right	−41.30	0	0
Left	40.79	0	0
SP apex			
Right	−22.61	−36.86	−19.52
Left	24.90	−32.14	−18.65

SP styloid process

The mean coordinate values of the bases and apexes of the SP were determined (Table 3). All SPs were shown from the anterior (Fig. 3b) and lateral (Figs. 4b, 5b). In the view of the SPs from the anterior and lateral, the mean coordinate values of the basis and apex, MA and AA values were shown on the coordinate plane (Figs. 3a, 4a, 5a).

Discussion

Eagle syndrome develops as a result of the elongation of the SP or calcification of the stylohyoid ligament. The elongated SP creates pressure on the adjacent structures and may cause some symptoms such as pharyngeal pain, a sense of a foreign body in the pharynx, headache, and otalgia. However, the presence of the elongated SP and calcified stylohyoid ligaments does not always lead to Eagle syndrome because many asymptomatic patients with the elongated SP have been reported [2, 11–13]. Patients with Eagle syndrome apply to many different clinics, such as otolaryngologist, neurosurgery, neurology, family medicine, psychiatry and dentistry due to non-specific clinical findings [13].

It is important to investigate the length of the SP that causes Eagle syndrome. However, it is not sufficient to know only the length of the SP because the deviations of the SP also affect the neighboring structures and cause Eagle syndrome. Despite the normal size of the SP, it has been reported that it can be palpated in the tonsillar fossa as a result of medial deviation [14]. Furthermore, lateral deviation causes compression in the external carotid artery. Posterior deviation irritates the last four cranial nerves. Anterior deviation leads to mucosal irritation and the tonsils compress the vital structures in the area [15, 16]. Therefore, studies investigating the length and the medial and anterior angulations of the SP have been carried out [11, 12]. Our study examined these parameters and determined the coordinates of the basis and apex of the SP that had not been encountered in the literature to date. These coordinates will show us where the SP apex can reach and will provide better information about the relationship with the neighboring structures.

In the study conducted on patients with Eagle syndrome, Buruldy et al. reported the mean SP length to be 40.3 mm and 40.5 mm on the right and left sides, respectively [11]. Kosar et al. reported the SP length to be 40 mm and 41 mm on the right and left sides, respectively, in patients with the pre-diagnosis of Eagle syndrome [12]. Okur et al. reported the SP length to be 40.7 mm and 40.3 mm on the right and left sides, respectively, in symptomatic patients with the elongated SP [13]. While these results are similar to the results of our study on the right side, the results of our study on the left side were found to be smaller. This may be due to the fact that most of the patients diagnosed with unilateral Eagle syndrome in our study received this diagnosis from the right side. Kent et al. reported the mean (right–left) length of the SP to be 48 mm [17]. Yavuz et al. also determined the SP length to be 50 mm and 52 mm on the right and left sides, respectively [18]. The results of Yavuz et al. [18] and Kent et al. [17] were found to be higher compared to our study and other studies. This may have originated from the fact that the studies by Buruldy et al. [11], Kosar et al. [12], Okur et al. [13] and our study were performed by the 3D-CT imaging method, whereas the measurements of Yavuz et al. [18] were made on Towne's graphy. It has been reported that the length of the SP can be evaluated in the best way on multislice CT, 3D-CT, multi-plane reconstruction and maximum intensity projection [13]. Furthermore, Pokharel et al. stated that 3D-CT reconstruction measured the length of the SP and its angulation correctly and is the gold standard in investigating its relationship with the neighboring structures [19]. Therefore, we believe that the results of other studies using 3D-CT and our study will be more reliable than the results of Yavuz et al. [18]. The difference between the results obtained by Kent et al. [17] and our results may be due to the difference in measurement techniques. Kent et al. [17] measured the SP length by rotating until an angle showing the entire long axis of the SP was obtained in 3D-CT. However, this method can be used only in 3D-CT. Considering the existence of clinicians who use imaging methods other than 3D-CT, we think that it may be more accurate to measure the SP length separately from the anterior or the lateral.

Upon investigating whether there is a difference between the SP lengths measured from the anterior and lateral on the right and left sides, it was determined that the lateral SP length was statistically significantly greater only on the left side ($p = 0.005$). This difference may be due to the greater anterior and medial angulations on the left side compared to the right side.

There was no statistically significant difference in the SP lengths between females and males. However, while the medial angulation of the SP was greater in males on both sides (significant on the right side $p = 0.003$), the anterior angulation of the SP was found to be greater on both sides in females (significant on the left side $p = 0.030$) (Table 2). According to these results of our study, it can be concluded that the SP may exhibit more medial and anterior deviation in females compared to males, thus causing Eagle syndrome.

While Burulday et al. [11] reported the MA values to be 69.4° and 68.9° on the right and left sides, respectively, Kosar et al. [12] reported them to be 66° and 69°, respectively. The MA in our study was found to be lower compared to these two studies because the low number of samples in the studies by Burulday et al. [11] ($n = 25$) and Kosar et al. [12] ($n = 22$) and the low number of samples used in our study ($n = 24$) may have caused the MA to change in a wide range.

While Yavuz et al. [18] reported the AA values to be 33.6° and 36.7° on the right and left sides, respectively, Okur et al. [13] reported them to be 16.1° and 16.7°, respectively. The reason for the smaller AA in our study in comparison with the study by Yavuz et al. [18] may be the fact that a different imaging method was used. The reason for the difference in our results from the results obtained by Okur et al. [13] may be the higher mean age of the selected patients in our study (the mean age in the study by Okur et al. was 44.8 years) because in our study, it was determined that the AA was positively correlated with age (right $r = 0.298$, left $r = 0.193$).

While the results on the MA in the studies conducted on asymptomatic samples related to the MA and AA [17, 20–23] were greater compared to our study, the results on the AA [13] were found to be smaller in comparison with our study. This situation may explain the development of Eagle syndrome as a result of the pressure of the SPs belonging to the samples in our study on the neighboring structures by exhibiting medial and anterior deviation.

As a result, the fact that our study has been conducted with the 3D-CT imaging method will provide detailed and reliable information about the SP length, angles, and coordinates. In the diagnosis of Eagle syndrome, it will be useful to know the length and angulation of the SP and to know the coordinates of the SP basis and apex. These results we have provided in relation to the SP coordinates will bring a new perspective to the authors who investigate the length and angulation of the SP. Therefore, we think that our results will be useful to physicians and researchers working in departments such as otolaryngology, radiology, neurosurgery, neurology, and dentistry.

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Compliance with ethical standards

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

Ethical approval "This article does not contain any studies with human participants or animals performed by any of the authors". Approval was obtained from Süleyman Demirel University Faculty of Medicine Clinical Research Ethics Committee (Date: 04.05.2019 Decision no: 130).

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