Eur Radiol (2005) 15:134–139
DOI 10.1007/s00330-004-2354-9

C. Çınar Başekim
Hakan Mutlu
Atila Güngör
Emir Şilit
Zekai Pekkafali
Murat Kutlay
Ahmet Çolak
Ersin Öztürk
Eşref Kizilkaya

Evaluation of styloid process by three-dimensional computed tomography

Received: 6 October 2003
Revised: 23 February 2004
Accepted: 5 April 2004
Published online: 19 June 2004
© Springer-Verlag 2004

C. Ç. Başekim (✉) · H. Mutlu · E. Şilit
Z. Pekkafali · E. Öztürk · E. Kizilkaya
Department of Radiology,
GATA Haydarpasa Teaching Hospital,
Kadikoy, 81327, Istanbul, Turkey
e-mail: cinarbasekim@yahoo.com
Tel.: +90-216-3462600
Fax: +90-216-3487880

A. Güngör
Department of Otolaryngology,
GATA Haydarpasa Teaching Hospital,
Kadikoy, 81327, Istanbul, Turkey

M. Kutlay · A. Çolak
Department of Neurosurgery,
GATA Haydarpasa Teaching Hospital,
Kadikoy, 81327, Istanbul, Turkey

Abstract The pupose of this paper was to investigate the length, medial angulations and other structural variants of the styloid process (SP) by three-dimensional computed tomography (3D CT) in patients without any complaints related to elongated SP. We performed temporal computed tomography (CT) scans in 138 cases (87 males, 51 females) with a mean age of 34.5 (17–86). The structure, length and medial angulation of SPs were evaluated on 3D reconstructed images. SP lengths varied between 1.58 and 5.48 cm (average length 2.83 cm), and the angles varied between 60.6 and 84.1° (average angle 69.4°). Other morphological findings were absence of SP (3 unilateral and 1 bilateral), ossification of stylohyoid ligament (9 unilateral and 27 bilateral), irregular SP (5 unilateral and 5 bilateral), fragmentation of SP (12 unilateral and 9 bilateral), absence of the proximal part (5 unilateral and 9 bilateral) and double proximal part (1 unilateral). According to our results, we propose a new classification. Absence of SP, absence of the proximal part of SP, duplication of the proximal part of SP and angle values of SP have never been reported before according to the available medical literature. 3D CT is an effective method in the evaluation of the SP length, angulations and other morphological characteristics.

Keywords Styloid process · Three-dimensional computed tomography · Eagle syndrome

Introduction

The styloid process (SP) is a long, cylindrical cartilaginous bone located on the inferior aspect of temporal bone, posterior to the mastoid apex, anteriomedial to the stylomastoid foramen and lateral to the foramen jugulare and canalis caroticus. The muscles and ligaments attached to SP have a role in mastication and swallowing. There are many vessels and nerves adjacent to the SP [1, 2].

SP of the temporal bone, cornu minus of the hyoid bone and stylohyoid ligament (SHL) form the stylohyoid complex. This chain connects the temporal bone to the hyoid bone. It is derived from the second branchial arch embryologically [2–5]. The chain consists of four structures:

– The tympanohyal part, which develops into the base of the process
– The stylohyal part, which becomes the main body of the process
– The ceratohyal part, which forms the SHL
– The hypohyal part, which matures into the lesser horn of the hyoid bone

The SP usually ossifies 5–8 years after birth [2, 3]. The ceratohyal element degenerates after a while, but its fibrous sheath remains as the SHL. The SHL is a connective tissue band originating from the apex of the SP and is attached to the lesser horn of the hyoid bone. Various degrees of ossification may be present in SHL because of the cartilaginous content of the ligament. Calcium deposition on the tip of the process can cause elongation of the SP [2, 3]. Variations in ossification and fusion of elements may present varying radiographic appearances.

Although there are numerous reports on SP length and on Eagle syndrome, we could not find any study on the medial angulations of SP in the available literature.

In this study, our purpose was to assess the length, medial angulations and other structural variants of SP by three-dimensional computed tomography (3D CT) in cases without any symptoms that could be related to elongated SP.

Materials and methods

One hundred thirty-eight patients (87 males, 51 females) were included in the study. The mean age was 34.5 years (range 17–36). All patients underwent temporal bone CT evaluation for different reasons (hearing loss, tinnitus, chronic otitis media, etc.), and none of them had any complaints related to SP. The structure, length and medial angulations of SP were evaluated on 3D reconstructed images that were obtained from these studies.

CT scans were obtained in the coronal plane (prone or hanging head position) with 1-mm slice thickness, 0.8-mm reconstruction increment, 16–18-cm FOV, 120 kV, 110 mA and 512×512 matrix size on Somatom Plus Spiral CT scanner (Siemens AG, Erlangen, Germany). An average of 65 images was obtained from each patient. The images were reconstructed with a real-time 3D (RT3D) interactive volume-rendering module of a workstation (3D Virtuoso CT/MR Workstation, Siemens AG, Germany), and 3D images were obtained using RT3D render.

The length between the attachment point of the SP to the temporal bone and the tip of the SP was measured (Fig. 1). If the cranial part of the SP was not visible, the length between the probable attachment point to the calvaria and the tip of the SP was measured. The ossification of SHL that joined SP was added to the measurement.

The angle between the line connecting the base of the SPs and the axis of the SP was also measured. The same method of measurement was used in cases with irregular and fragmented SPs. The general structural appearances of SP and calcifications and ossifications of SHL were also evaluated.

The length and the angle were recorded separately for each side since there were some differences between the right and left sides in some cases. SP was not detected in three cases bilaterally and in one case unilaterally. Two hundred sixty-nine SPs in 138 cases were evaluated morphologically.

Patients were grouped according to sex and age. SPs were evaluated for their average lengths and angles in different sex and age groups. Patients were divided into three groups according to the length of the SP. The number and mean angle values of SPs in each group were determined. Cases were also divided into five groups according to the angle values. The number and length of SPs were calculated in each group. The ANOVA test was used to compare groups, and the Scheffe test was used as a post hoc test in the statistical analysis.

Results

SPs were absent unilaterally in three cases and bilaterally in one (Fig. 2). Evaluations were made in 269 SPs in 138 patients for this reason. SP lengths varied between

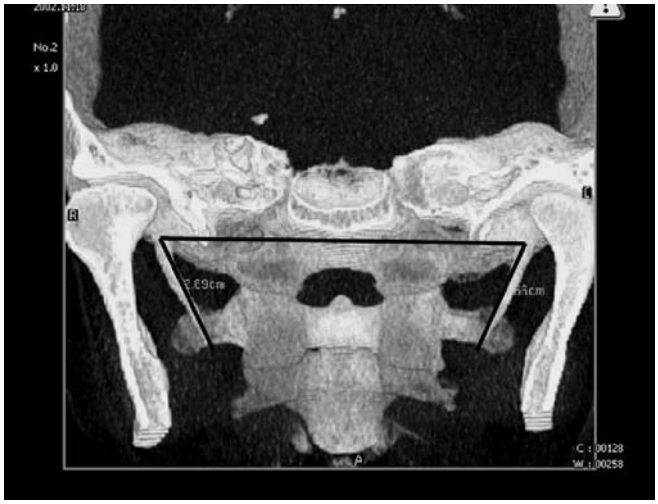

Fig. 1 Measurement of length and angle of SP

Fig. 2 Bilateral absence of SP

Fig. 3 Short SP: *right* SP is 1.86 cm and *left* SP is 1.73 cm

1.58 and 5.48 cm (mean 2.83 cm), and the angles varied between 60.6 and 84.1° (mean 69.4°) (Figs. 3, 4, 5, 6). Mean length and angle values of SPs according to sex are summarized in Table 1,and mean length and angle values of SPs according to age groups are summarized in Table 2.

Fig. 4 Elongated SP: *right* SP is 4.66 cm and *left* SP is 4.57 cm

Fig. 5 Angle value is 62.1° on *right* side and 60.6° on *left* side

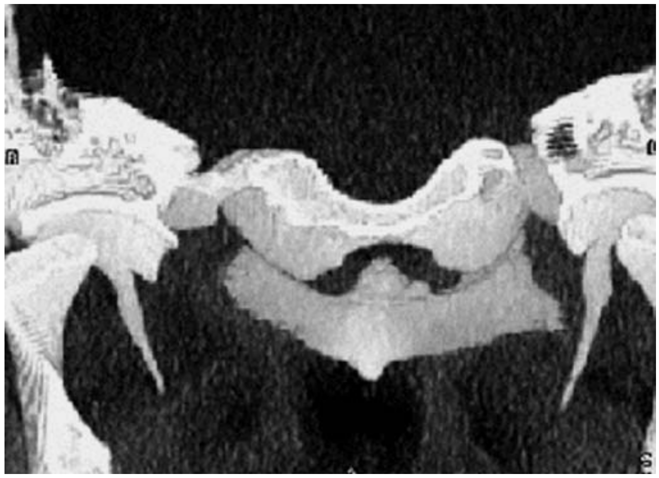

Fig. 6 Angle value is 79.6° on *right* side and 76.2° on *left* side

Fig. 7 Unilateral bent SP

Table 1 Mean length and angle values (minimum–maximum–±standard deviation) of SPs according to sex

Sex	No. of patients	Mean length (min–max–±SD)	Mean angle (min–max–±SD)
Male	87	2.91 cm (1.58–5.48–±0.79)	70.51° (61.8–84.1–±4.20)
Female	51	2.68 cm (1.81–4.63–±0.66)	68.72° (60.6–81.3–±4.20)
Total	138	2.84 cm (1.58–5.48–±0.76)	69.5° (60.6–84.1–±4.27)

Table 2 Mean length and angle values of SPs according to age groups

Age group (years)	No. of patients	Mean length (min–max)	Mean angle (min–max)
0–20	21	2.51 cm (1.86–3.59)	70.76° (61.8–81.3)
21–40	69	2.95 cm (1.60–5.48)	70.22° (60.6–84.1)
41–60	30	2.81 cm (1.76–4.63)	69.23° (62.7–81.1)
Over 60	18	2.66 cm (1.58–4.66)	68.74° (62.2–76.0)

The number and average angle value of SPs in different length groups are summarized in Table 3, and the number and average length of SP in different angle groups are summarized in Table 4.

In addition, ossification of SHL (9 unilaterally and 27 bilaterally), irregular SP (5 unilaterally and 5 bilaterally), fragmentation of SP (12 unilaterally and 9 bilaterally), absence of the proximal part (5 unilaterally and 9

Fig. 8 Bilateral absence of proximal (ceratohyal) part of SP

Fig. 9 Double proximal part of SP on the *right* side and fragmentation on *left* side

Fig. 10 Elongated SP on the *left* side and ossification of SHL on the *right* side

bilaterally) and double the proximal part (1 unilaterally) were detected in these patients (Figs. 7, 8, 9, 10).

There was no statistically significant difference between the length and angle values in different sex and age groups. There was also no statistically significant difference between the angle values of SP in different length groups and length values of SP in different angle groups.

Table 3 Classification of SP according to the length and average angle values in these groups

Length (cm)	No. of SP (%)	Mean angle (min–max)
<2.00	34 (12.6)	70.55° (60.6–82.9)
2.01–4.00	209 (77.7)	69.88° (60.8–84.1)
>4.01	26 (9.7)	69.37° (64.3–75.1)

Table 4 Classification of SP according to the angle values and average length values in these groups

Angle (°)	No. of SP (%)	Mean length (min–max)
<65	31 (11.5)	2.81 (1.88–4.52)
65.1–70	102 (37.9)	2.94 (1.81–5.48)
70.1–75	108 (40.2)	2.80 (1.58–4.51)
75.1–80	20 (7.4)	2.64 (1.89–4.57)
>80.1	8 (3.0)	2.63 (1.83–3.19)

Discussion

The elongated SP and structural changes in SHL with its clinical symptoms were first described by Eagle. For this reason, these are known as the Eagle's syndrome. Eagle reported that the normal length of the SP was 2.5 cm, and the values higher than that may represent elongation of the SP, the incidence of which was 4% in the same study.

The symptoms associated with Eagle's syndrome are directly related to the anatomic relationship between the SP and surrounding structures [1–3]. The elongated SP can project into the tonsillar neck and pharynx; it can cause some symptoms because of compression on some neural and vascular structures. These symptoms are ipsilateral pain, radiating to the ear, face and neck, sensation of a foreign body during swallowing or vertigo attacks during sudden contralateral head movements. Some miscellaneous complaints such as tinnitus, hypersalivation and episodic pain with muscular spasm can also be seen in these patients. The most common complaint is earache [1–4, 7–10].

The full length of SP must be visualized for its measurement [1, 2, 11]. The conventional methods that are used for detecting elongated SP are the palpation of tonsillar fossa, direct radiographic studies (such as transorbital petrous radiographs, cervical, mastoid, lateral and lateral-oblique mandibular and submentovertical radiographs), and panoramic radiographs. But the visualization is not easy on conventional radiographs. The mandibular bone and the teeth superimpose on SP and reduce the quality of the image on conventional radiographs. 2D and 3D CT can overcome these superimpositions [1, 2, 5, 8, 11].

Both axial and coronal planes in temporal bone CT imaging are recommended [12, 13], and this is what we do in our routine temporal bone CT examinations. We used the coronal plane in demonstrating 3D CT of the SP. It was depicted by an average of 65 images in all cases. Nakamura and colleagues [11] did not mention which section plane was used in 3D CT of four cases, but they used 120 images to achieve reconstructed images in each case. Half of this image number can reveal temporal bone and SP in the coronal plane, and if the aim is to reveal SP only, a smaller number of images may be enough.

Measurements obtained with different modalities revealed that the normal length of the process varies from 1.5 to 6.0 cm, and the average length varies from 2.0 to 3.2 cm [1–5, 7, 8, 10]. It was reported that the length of SP in different age and sex groups was not significantly different in these studies, and our results are similar.

The prevalence of elongated and symptomatic SP is not thoroughly known [1, 3]. It was reported that the incidence of the long SP was 0.4–50% in the population, and of these only half (or less) were symptomatic. We believe that this variation depends on assuming different lengths as normal for SP in different studies. This was 2.5 cm in some studies and 4 cm in others. It was reported that SP length above these values might cause symptoms [1, 2]. We think that the reason for the variations in these measurements of SP in various studies was that different imaging methods, which could not demonstrate SP accurately, were used in those studies. We did not see any symptoms in cases who had elongated SPs. That is why we believe that symptoms not only depend on the length, but also on some other reasons like angulation.

Generally, no correlation has been found between the severity of complaints and the length of stylohyoid chain ossification in symptomatic patients [1, 3]. It has been reported that abnormal angulations rather than elongation of the process is responsible for some concentrated symptoms [1]. However, we could not find any study on this. We have observed in our study that angles range from 60.6 to 84.1°. We think that when the angle of SP is narrow, it may produce some complaints because of compression of adjacent structures. Our study has revealed that the length and angle values of sexes and different age groups were not significantly different. Also, there was no correlation between the angle and the length of SP.

When whole SHL ossifies, it forms a solid structure and may produce some symptoms. Sudden movement of the head can lead to fracture of the SP or an ossified SHL [2, 3, 9]. In our study, we did not see any anomalies such as total ossification of the SHL.

Various authors reported variations of the SP and related structures, such as ossification of the whole SHL, ram's horn, elongated, segmented, pseudoarticulated, jointed, nodular, bent or partial ossification [2, 9]. There is no report on the absence (total or proximal part) of the SP and the double proximal part of the SP in the available literature. We think this is because other imaging methods cannot demonstrate the cranial part of the SP. 3D CT can reveal these variations clearly.

It was reported that elongation of the SP is almost bilateral; however, we found that the length, angle value and morphological characteristics of the SP may be different in the same patient, so each SP must be evaluated separately.

Several classifications of the SP according to shape and length have been reported previously. But none of these classifications included the angulation and morphological findings first described in this paper. We suggest a new classification based on the length, angulation and morphology of the SP. We call it the "LAM" (length, angulation and morphology) classification:

L: Length of the SP
1. Short (<2.00 cm)
2. Long (2.00–4.00 cm)
3. Elongated (>4.00 cm)

A: Angulation of the SP
1. Narrow (<65.0°)
2. Normal (65.0–75.0°)
3. Wide (>75.0°)

M: Morphology of the SP
0. Absence of SP
1. Normal appearance of SP
2. Other morphological findings (absence of the proximal part of the SP, duplication of the proximal part of the SP, bent SP, segmented SP, pseudoarticulated SP, etc.)

Our results suggest that 3D CT is an effective method in the evaluation of SP length, angulation and other morphological characteristics. Absence of the SP, absence of the proximal part of the SP and duplication of the proximal part of the SP have been reported for the first time in our study, and our study has revealed the superiority of 3D CT in the morphological evaluation of the SP. Correlation of the clinical findings concerning the length and angle values of SP requires further studies with a large number of symptomatic cases.

Acknowledgments This study was presented at the European Congress of Radiology 2003 and was awarded with Cum Laude.

References

1. Yetiser S, Gerek M, Ozkaptan Y (1997) Elongated styloid process: diagnostic problems related to symptomatology. Cranio 15:236–241
2. Gozil R, Yener N, Calguner E, Arac M, Tunc E, Bahcecioglu M (2001) Morphological characteristics of styloid process evaluated by computerized axial tomography. Ann Anat 183:527–535
3. Bafageeh SA (2000) Eagle syndrome: classic and carotid artery types. J Otolaryngol 29:88–94
4. Keur JJ, Campbell JPS (1986) The clinical significance of the elongated styloid process. Oral Surg Oral Med Oral Pathol 67:399–404
5. Camarda AJ, Deschamps C (1989) Stylohyoid chain ossification: a discussion of etiology. Oral Surg Oral Med Oral Pathol 67:515–520
6. Eagle WW (1937) Elongated styloid process: report of two cases. Arch Otolaryngol 25:584–587
7. Palesy AP, Murray GM, De Boever J, Klineberg I (2000) The involvement of the styloid process in head and neck pain—a preliminary study. J Rehabil 27:275–287
8. Monsour PA, Young WG (1986) Variability of the styloid process and stylohyoid ligament in panoramic radiographs. Oral Surg Oral Med Oral Pathol 61:522–526
9. Satyapal KS, Kalideen JM (2000) Bilateral styloid chain ossification: case report. Surg Radiol Anat 22:211–212
10. Fini G, Gasparini G, Filippini F, Becelli R, Marcotullio D (2000) The long styloid process syndrome or Eagle's syndrome. J Craniomaxillofac Surg 28:123–127
11. Nakamura Y, Fukuda S, Miyashita S, Ohashi M (2002) Diagnosis of the elongated styloid process by three-dimensional computed tomography. Auris Nasus Larynx 29:55–57
12. Nayak S (2001) Segmental anatomy of the temporal bone. Semin Ultrasound CT MRI 22:184–218
13. Davidson HC (2001) Imaging evaluation of sensorineural hearing loss. Semin Ultrasound CT MRI 22:229–249