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Original Article

Radiology Section

Evaluation of Styloid Process Length using Multidetector Computed Tomography Scan in Indian Population: A Cross-sectional Study

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ABSTRACT

Introduction: The length of the Styloid Process (SP) has been a subject of research since Eagle's case report on a syndrome characterised by symptoms related to a painful elongated SP. Various modalities including orthopantomogram, digital radiography, cadaveric measurements, and Multidetector Computerised Tomography (MDCT) scanning have been used to study SP length. The present study aims to determine the normal SP length in the Indian population, specifically among armed forces personnel, using MDCT scans.

Aim: To measure the SP length in the Indian population using MDCT scans and establish a cut-off length to define elongation.

Materials and Methods: A single centre cross-sectional study was conducted at the Department of Radiology, Command Hospital Pune, Maharashtra, India from January 2023 to March 2023. The SP length was measured in 402 patients referred for CT scans of the head and Paranasal Sinus (PNS), utilising 3D Multiplanar Reformation (MPR), curved reformat, and volume rendering techniques. The patients were divided into six age groups: Group I (<20 years), Group II (21 to 30 years), Group III (31 to 40 years), Group IV (41 to 50 years), Group V (51-60 years), and Group VI (>60 years). Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) Version 28.0, and significance was set at p-value <0.05.

Results: Among the 402 patients, 210 were males, and 192 were females, with a mean age of 43.8±16.7 years. The mean SP length across all patients was 23.24±3.92 mm. The mean length was 23.74±4.50 mm on the right side and 22.74±3.72 mm on the left side, with no statistically significant difference between them (p-value=0.058). There was a significant gender difference, with males having a mean length of 23.67±4.12 mm and females 22.77±3.64 mm (p-value=0.011). The SP length increased significantly with age, demonstrating a notable difference between age groups. The upper limit of normal (90th percentile) ranged from 25.74 mm for patients <20 years to 28.91 mm for patients >60 years.

Conclusion: A statistically significant difference in SP length was observed between genders, with a significant increase in length with age. In the Indian population, an SP length greater than 28 mm should be considered elongated.

Keywords: Eagle's syndrome, Indian armed forces personnel, Volume rendering techniques

INTRODUCTION

The Styloid Process (SP) is a needle-like cylindrical bony projection that originates from the base of the petrous temporal bone. It develops from Reichert's cartilage, which forms from the second pharyngeal arch during embryological development. Positioned antero-inferior to the external auditory meatus, anteromedial to the mastoid process, and anterior to the stylomastoid foramen [1,2], the SP consists of a proximal base within the vaginal process of the temporal bone and a distal shaft from which the stylohyoid, styloglossus, and stylopharyngeus muscles arise [3-5]. Ligaments, namely the stylomandibular and stylohyoid ligaments, connect the tip of the SP to the ramus of the mandible and the hyoid bone, respectively [6]. Surrounding the SP are vital neurovascular structures, including the internal and external carotid arteries, internal jugular vein, and cranial nerves V, VII, IX, X, XI, and XII. The SP serves as a surgical landmark, dividing the parapharyngeal space into prestyloid and poststyloid compartments [7]. However, the clinical significance of the SP lies in the constellation of symptoms associated with Eagle's syndrome [8].

The classical Eagle's syndrome manifests as neck pain radiating to the face, jaw, and ear, exacerbated by movement of the neck, face, and tongue during chewing and swallowing. It is characterised by irritation of adjacent nerves and a foreign body sensation in the pharynx. It can also have a non-classical presentation, where compression of the carotid arteries, their branches, and the accompanying nerve plexus by an elongated SP can lead to eye pain, cluster headaches, syncopal attacks, and visual changes, resulting from internal carotid artery vascular insufficiency. [9-11]. In some cases, an elongated SP has been reported to cause dissection of the internal carotid artery, leading to transient ischaemic attacks and ischaemic stroke [10,12]. Studies have been conducted worldwide, including in India, to determine the normal length of the SP using various measurement tools and diagnostic modalities such as cadaveric measurements, diagnostic radiography, and computed tomography [6,13-21]. The latest modality employed is 3D-CT scan using volume rendering techniques. These studies have revealed a wide range of average SP lengths, highlighting population-specific differences. However, no comprehensive study has been conducted in India to determine the SP length in a representative sample encompassing various regions and ethnicities of the country. Therefore, the present study aims to measure the SP length in the Indian population, specifically among armed forces personnel, using 3D-volume rendering techniques on a MDCT machine. The study also seeks to evaluate the dependence of SP length on gender and age and establish a cut-off length for defining elongation.

MATERIALS AND METHODS

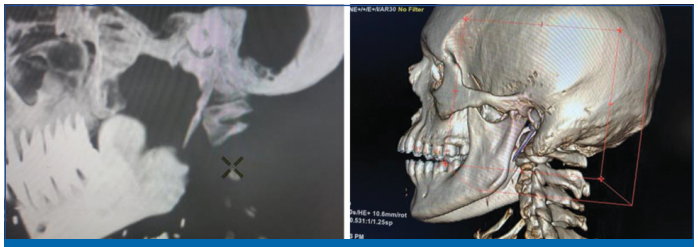
The present single centre cross-sectional study was conducted at the Radiology Department of Command Hospital, Pune,

Maharashtra, India. The study was carried out between January 2023 and March 2023, and patients presenting to the Radiology Department during this period were included. Institutional Ethics Committee approval {214/2023/ CHSC} was obtained, and informed consent was obtained from all participants.

Inclusion and Exclusion criteria: The study included patients aged 10 to 85 years who presented for CT scans of the head and Paranasal Sinus (PNS) for various indications such as headache, trauma, and sinusitis. Patients whose SP was fractured, not clearly visualised due to artifacts, or not completely included in the scan were excluded. Patients with symptoms suggestive of Eagle's syndrome were also excluded.

Study Procedure

A total of 402 patients were included in the study. CT scans were performed using a GE CT scan model Revolution Evo, a 128-slice CT scanner, with a slice thickness of 0.625 mm. The thin section images were transferred to the AW Volume Share 7 workstation [22] for evaluation by a single radiologist with 20 years of experience in Diagnostic Radiology. The workstation was used to process the images and employ 3D Multiplanar Reformation (MPR), curved reformat, and volume rendering techniques [Table/Fig-1]. The SP length was measured on the curved reformat image, from its base to its tip, using straight line and curved line measuring tools for straight and curved SP, respectively. Three measurements were taken on each side in each patient, and the average was recorded. The data was then tabulated and grouped according to gender and age. Six age groups were created: Group I (<20 years), Group II (21 to 30 years), Group III (31 to 40 years), Group IV (41 to 50 years), Group V (51-60 years), and Group VI (>60 years).



[Table/Fig-1]: Curved reformat (left image) and volume rendered image (right image) of the styloid process by MDCT scan showing measuring tool.

STATISTICAL ANALYSIS

The data analysis was performed using SPSS Version 28.0 (IBM Corp., Armonk, NY, USA). Categorical variables such as gender and age group were expressed as frequency and percentage (%). Continuous variables were described using descriptive statistics, including mean, Standard Deviation (SD), median, Interquartile Range (IQR), and percentiles. The normality of the average length (mm) was assessed using a Q-Q plot and the Kolmogorov-Smirnov (KS) test. The Mann-Whitney U test was used to compare the average length (mm) between males and females. The Kruskal-Wallis (KW) test was employed to compare the average length (mm) among different age groups. Spearman's correlation coefficient was used to determine the correlation between age (years) and average length (mm). A p-value <0.05 was considered statistically significant.

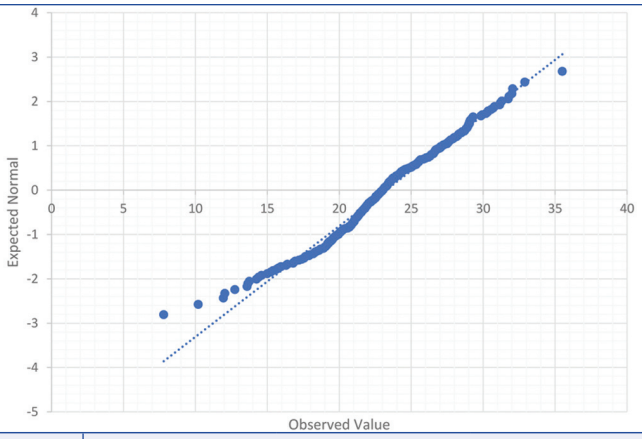
RESULTS

A total of 402 patients participated in the study, with a mean age of 43.8±16.7 years. The mean age for males was 43.88±17.33 years, and for females, it was 43.81±16.44 years (p-value = 0.964) [Table/Fig-2].

Age group (years)	Gender		Total (N)
	Male n (%)	Female n (%)	
≤20	15 (65.2)	8 (34.8)	23
21-30	43 (47.3)	48 (52.7)	91
31-40	41 (54.7)	34 (45.3)	75
41-50	43 (53.8)	37 (46.3)	80
51-60	30 (50.8)	29 (49.2)	59
> 60	38 (51.4)	36 (48.6)	74
Total	210	192	402

[Table/Fig-2]: Age and gender distribution of study participants.

Styloid Process (SP) length: The mean length of the SP in the 402 patients was 23.24±3.92 mm. On the right side, the mean length was 23.74±4.50 mm, and on the left side, it was 22.74±3.72 mm. The cumulative lengths of the SP on both sides did not show a significant difference (p-value=0.058). Therefore, the mean length of the right and left SPs was used for each patient. A total of 402 mean lengths were available. The normality of the SP lengths was tested using a Q-Q plot and the Kolmogorov-Smirnov test, indicating that the data did not follow a normal distribution [Table/Fig-3].



Average	Kolmogorov-Smirnov		
	Statistic	df	p-value
	0.062	402	<0.001

[Table/Fig-3]: Q-Q plot for normality of average length of styloid process.

Styloid Process (SP) length and dependency on gender: The median (IQR) SP length for males was 23.50 (21.25-26.59) mm, and for females, it was 22.55 (21.03-24.64) mm. The difference in SP length between genders was statistically significant, as determined by the Mann-Whitney U test {p-value=0.011 (<0.05)} [Table/Fig-4].

Gender	Average Length (mm)						p-value
	N	Mean	SD	Min	Max	Median	
Male	210	23.67	4.12	7.80	35.50	23.50	0.011
Female	192	22.77	3.64	11.95	32.05	22.55	
Gender	Average Length (mm)						
	Q1	Q3	P5	P10	P90	P95	
Male	21.25	26.59	17.62	19.29	28.76	28.76	
Female	21.03	24.64	16.36	18.72	27.49	28.95	

[Table/Fig-4]: Average length of SP in males and females along with percentile distribution.

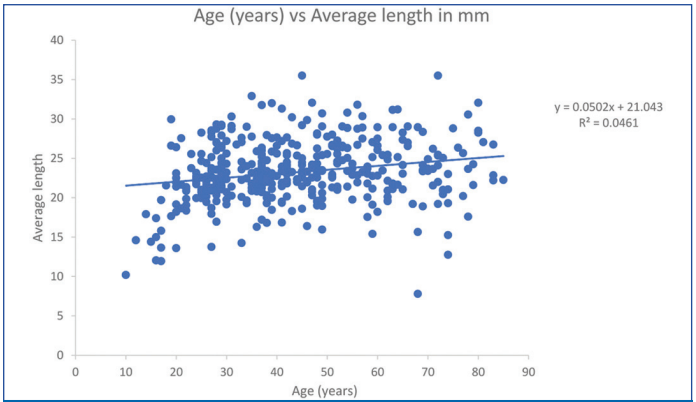
Styloid Process (SP) length and dependency on age: There was a significant difference in SP length among different age groups (p-value <0.001), as determined by the Kruskal-Wallis test [Table/Fig-5].

The correlation coefficient (Spearman's correlation coefficient) between SP length and age (years) was 0.227 (p-value = 0.001), indicating a poor positive correlation. The linear regression line

equation for SP length (y) with age (x) is y = 0.050x + 21.04. The p-value for the slope was <0.05, suggesting that as age (years) increases, there is a significant increase in the length of the SPs [Table/Fig-6].

Age group (years)	Average length (mm)					
	N	Mean	SD	Min	Max	Median
≤20	23	18.46	5.14	10.20	29.95	17.90
21-30	91	22.78	3.03	13.75	29.30	22.35
31-40	75	23.44	3.59	14.25	32.90	22.95
41-50	80	23.61	3.61	15.95	35.50	23.35
51-60	59	24.42	3.38	15.40	31.80	24.30
>60	74	23.73	4.46	7.80	35.50	23.65
Age group (years)	Average length (mm)					
	Q1	Q3	P5	P10	P90	P95
≤20	14.50	21.73	11.96	12.36	25.74	26.58
21-30	20.93	24.40	18.68	19.55	27.55	28.43
31-40	21.25	25.73	18.08	19.79	27.87	29.46
41-50	21.75	25.36	18.59	19.49	28.24	30.23
51-60	22.63	26.70	19.01	20.81	28.86	29.18
>60	21.06	26.50	16.92	19.23	28.91	30.76

[Table/Fig-5]: Mean length, median length and percentile distribution of SP lengths for different age groups.



[Table/Fig-6]: Scatter plot for age in years and average length of SP.

DISCUSSION

The authors conducted the statistical analysis based on the number of patients rather than the number of styloid processes (SP). They chose to take the mean of the right and left-side SP lengths for each patient because there was no significant difference between the lengths on both sides and to avoid errors in demographic variables. The mean length of the SP was 23.67 mm (SD 4.12 mm) in males and 22.77 mm (SD 3.64 mm) in females. These findings were comparable to a study by Shayganfar et al., where the mean SP length was 25.3 mm (SD 7.1 mm). Other studies using MDCT to evaluate SP length have reported a wide range of values, ranging from 25.3 mm to 37.9 mm. Two Indian studies were found that assessed the mean SP length using MDCT. The mean SP lengths from these Indian and international studies were compared and presented in [Table/Fig-7] [14,15-17,19,21,23-25]. The mean length was higher in males compared to females, which was consistent with the findings of Shah O et al., and Ekici et al., The difference between genders was statistically significant in this study (p-value = 0.011).

There was a significant increase in SP length with age, which was similar to the findings of Jung et al., However, this finding contradicted the results of Cullu N et al., Shah O et al., and Ekici et al., who found no significant difference in mean SP lengths with age. This may be attributed to racial and geographical variations. The upper limit of normal SP length has been proposed differently by various authors. Eagle proposed a limit of 25 mm [26], Basekim CC et al., suggested 40 mm, and Ramadan et al., recommended 30 mm. In this study, the data for mean SP length did not follow a normal distribution, so the upper limit of normal could not be determined by mean plus two standard deviations. Instead, the 90th percentile was considered an appropriate measure, ranging from 25.74 mm for patients in the <20 years age group to 28.91 mm for patients in the >60 years age group. The 90th percentile for SP length was 28.76 mm for males and 27.49 mm for females.

Study	Place and year of study	Mean SP length (SD) in mm
Priyadharshini S et al., [21]	India, 2022	36.7 (6.2)
Shah O et al., [19]	India, 2021	31.3 (4.5)
Basekim CC et al., [14]	Turkey, 2005	28.3 (7.9)
Gözil R et al., [15]	Turkey, 2001	28.4 (12.4)
Cullu N et al., [16]	Turkey, 2013	28.4 (5.5)
Shayganfar A et al., [17]	Iran, 2018	25.3 (7.1)
Onbas O et al., [23]	Turkey, 2005	26.8 (10.0)
Ramadan SU et al., [24]	Turkey, 2007	27.0 (11.1)
Ekici F et al., [25]	Turkey, 2012	29.6 (10.5)

[Table/Fig-7]: Mean SP length in various studies [14-17,19,21,23-25].

The strength of the present study is its representative sample of armed forces personnel, which makes it applicable to various population subgroups in India. Future recommendations include conducting similar studies in different population subgroups and comparing the results with the present study. The upper limit of normal SP length determined in the present study can aid surgeons in diagnosing and managing cases of Eagle's syndrome in the Indian population.

Limitation(s)

Limitations of the study include the measurement of only SP length without considering the orientation of the SP, which may also influence the presenting symptoms of Eagle's syndrome in the study subjects.

CONCLUSION(S)

Based on the findings of the present study, there was no significant difference in the length of the styloid process (SP) on the right and left-sides. However, the mean length of the SP was higher in males compared to females. There was also a significant increase in SP length with increasing age. Therefore, the authors suggest that an SP should be considered elongated in the Indian population, if its length exceeds 28 mm.

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