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Using the anteroposterior diameter of C3-C7 spinal canals to assess cervical stenosis among Ghanaian males: An anatomical study

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ABSTRACT

Background and aim: Cervical stenosis (CS) occurs when the size of the spinal canal is narrower in an individual than that of the general population. Individuals with CS may be asymptomatic or may present with a wide array of neurological symptoms. There however appears to be paucity of information on the AP canal diameter among Ghanaians. This study therefore, aimed at using the diameter of C3-C7 spinal canals to assess the presence of cervical stenosis in the Ghanaian male population.

Material and Methods: The study was carried out using 110 dry cervical vertebrae which the author harvested from 24 male cadavers. The anteroposterior diameter (AP) of the cervical spinal canal for C3-C7 vertebrae were measured using a digital Vernier caliper to 0.01mm precision. Using the means and standard deviations, the spinal canals were classified as relatively narrow or narrow.

Results: The percentage of narrow and relatively narrow spinal canals was 1.82% (2) and 10.0% (11) respectively. The C4 vertebra was observed to have the smallest AP diameter 12.38±2.12mm, while C6 had the largest AP diameter 13.88±1.47mm. AP diameters in the present study were found to differ from Caucasians and African-American males, but were similar to those reported in Asians and Female African-American females.

Conclusion: In the present study 11.8% of cervical vertebrae showed some degree of narrowing. The mean AP diameters of the spinal canals in the present study were found to be smaller than those reported in Caucasians and African American males. The findings of the present study suggest the need to develop race and geographic specific criteria for diagnosing CS.

Keywords:

Cervical Stenosis; Spinal Canal; Cervical Vertebra; Ghana

INTRODUCTION

The design of the bony spinal canal protects the spinal cord, which lies within it from shocks that may result in injury. There is usually a space of approximately 1 to 3 mm between the spinal cord and its bony cage (Tatarek, 2005). This space serves as a “buffer” and allows for slight changes to occur within the canal without impacting the spinal cord therein (Tatarek, 2005). Cervical stenosis (CS) occurs when the spinal canal is greatly narrowed as a result of an abnormal bony anatomy (Lee *et al.*, 2007). This puts the spinal cord and other structures within the canal at a greater risk of injury.

Individuals with CS may be asymptomatic or they may present with a wide array of neurological symptoms of varying severity (Bajwa *et al.*, 2012; Goodwin and Hsu 2023). The onset and severity of neurological injury has been linked to diameter of the spinal canal prior to injury (Eismont *et al.*, 1984; Kang *et al.*, 1994; Tatarek, 2005; Lee *et al.*, 2007).

The anteroposterior (AP) diameter of the cervical

canal is one of the means by which CS is diagnosed (Lee *et al.*, 2007; Goodwin and Hsu 2023). Earlier work by Tatarek, (2005) used the mean AP diameters at the various spinal levels and their standard deviations to calculate cut-off values which was then use to classify cervical spinal canals as average, relatively narrow or narrow. Other studies have also defined CS as an anteroposterior (AP) canal diameter that measures < 11-14mm (Tierney *et al.*, 2002; Lee *et al.*, 2007; Goodwin and Hsu 2023). Evidence in literature points to the fact that the AP diameter of cervical spinal canal vary greatly among different races and ethnicities (Chazono *et al.*, 2012), making it difficult to have a common cut off point for all populations.

The need to develop ethnic or race specific criteria for determining cervical canal narrowing and subsequently CS is therefore important. There appears however, to be little to no information on the AP dimensions of the cervical canal in the Ghanaian population. This study therefore

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aimed at examining the AP diameters of C3-C7 spinal canals as a means to assess the presence of cervical canal stenosis in the Ghanaian population.

MATERIALS AND METHODS

Study Design

The study was carried out using 110 dry cervical vertebrae (C3-C7) that had been harvested by the author from 24 male cadavers (24 cervical spine segments). These cadavers had been donated to the Department of Anatomy and Cell Biology, School of Medical Sciences, University of Cape Coast for purposes of academic dissection. The bones were boiled, air dried and stored at the Department's bone room. The breakdown of the number of vertebrae harvested at each spinal segment was as follows; C3-22, C4-23, C5-24, C6-23, C7-18. The anteroposterior (AP) diameter which was defined as the midsagittal distance from the posterior-most aspect of the vertebral body to the anterior-most aspect of the spinolaminar complex (Lee *et al.*, 2007), was measured for C3-C7 vertebrae (figure 1) using a digital Vernier caliper to 0.01mm precision. The mean and the standard deviation (SD), of the AP diameter was calculated for each spinal level.



Figure 1. The anteroposterior (AP) diameter: midsagittal distance between the posterior-most aspect of the vertebral body and the anterior-most aspect of the spinolaminar complex of a C5 cervical vertebra as indicated by the arrow.

Using the means and standard deviations, the spinal canals were classified as “relatively narrow” or “narrow” by means of the criteria developed by Tatarék (2005). Spinal canals that measured 2 SD below the mean were classified as “narrow”. Canals that measured between 2 SD and 1 SD below the mean were defined as “relatively narrow”.

Exclusion Criteria

Vertebrae that had osteophytes, degenerative changes or deformed were excluded from this study.

Analysis

IBM Statistical Package for Social Sciences (SPSS) version 27 was used for data analysis. The mean AP diameter and their standard deviations for each spinal level was calculated. A One-way analysis of variance (ANOVA) test was used to determine any significant differences in the mean AP diameters between the various spinal levels at a significance of 0.05.

RESULTS

The mean AP diameter of the cervical spinal canals was 13.44 ± 1.78 mm. The C4 vertebra was observed to have the smallest mean AP diameter of 12.86 ± 2.12 mm, while the C6 vertebra was found to have the largest mean AP diameter of 13.88 ± 1.47 mm (Table 1). There was no significant statistical difference in the mean AP diameters when comparison was made between the various spinal levels using One way ANOVA ($p=0.23$). The cut off value for relatively narrow spinal canals ranged from 8.62-12.36mm (Table 1).

Table 1. The Mean Anteroposterior Diameters of C3-C7 Vertebrae and their Cut-off Point for Narrow and Relatively Narrow

		AP Diameter(mm)	Mean AP Diameter $\pm$ SD (mm)
C3	Relatively Narrow	9.30-11.21	13.13 $\pm$ 1.92
	Narrow	<9.30	
C4	Relatively Narrow	8.62-10.74	12.86 $\pm$ 2.12
	Narrow	<8.62	
C5	Relatively Narrow	10.19-11.86	13.53 $\pm$ 1.67
	Narrow	<10.19	
C6	Relatively Narrow	10.93-12.40	13.88 $\pm$ 1.47
	Narrow	<10.93	
C7	Relatively Narrow	10.86-12.36	13.86 $\pm$ 1.50
	Narrow	<10.86	

Table 2. The Frequency of Narrow and Relatively Narrow Vertebrae at each Spinal Level.

	C3 n=22 (%)	C4 n=23(%)	C5 n=24 (%)	C6 n=23(%)	C7 n=18 (%)	Total (%)
Relatively Narrow	2(9.1)	2(8.7)	4(16.7)	2(8.7)	1(5.6)	11(10.0)
Narrow	1(4.5)	1(4.3)	0(0.0)	0(0.0)	0(0.0)	2 (1.82)
Total	3(13.6)	3(13.0)	4(16.7)	2(8.7)	1(5.6)	13(11.8)

A total of 13 (11.8%) cervical vertebrae showed some degree of cervical narrowing. The percentage of narrow and relatively narrow spinal canals was 1.82% (2) and 10.0% (11) respectively. The narrow spinal canals were located in C3 and C4, the relatively narrow spinal canals were observed at all spinal levels (Table 2).

Six of the 24 cervical spine segments were found to possess one stenotic vertebra (either narrow or relatively narrow) (Table3).

Table 3. The Frequency of Stenotic Vertebrae in each Cervical Spine Segment

No. of Stenotic Vertebrae	No. of Cervical Spine Segment
1	6
2	0
3	1
4	1
5	0

DISCUSSION

The present study found that 13 (11.8%) cervical vertebrae showed some degree of cervical narrowing. This is lower than the 19.2 % that was reported by Lee et al. (2007). The percentage of narrow and relatively narrow spinal canals was 1.82% (2) and 10.0% (11) respectively. The mean AP spinal canal diameter in this study was 13.44 ± 1.78 mm. This is lower than the mean AP diameter of 14.0 ± 2.0 mm reported in Blacks and the mean of 14.2 ± 1.6 mm observed in Whites (Lee et al., 2007). The smallest mean AP diameter was observed in the C4 vertebra. This observation is consistent with findings of previous studies which utilized either imaging techniques or direct measurement of bones to determine the AP diameter of the cervical spinal canals (Hashimoto and Tak, 1977; Gupta et al., 1982; Herzog et al., 1991; Lee et al., 1994; Maqbool et al., 2003; Tatarek, 2005; Chazono et al., 2012; Sureka et al., 2018; Lee et al., 2021; Griffith and Lee 2024). Some studies have reported that from the C4 vertebra the AP diameter increases caudally. Thereby, giving the spinal canal of the cervical region an hour glass shape (Lee et al., 1994; Maqbool et al., 2003; Tatarek, 2005; Lee et al., 2007; Sureka et al., 2018). This was however contrary to the observations of the present study. Similar to the findings of Lee et al (2021) no significant statistical difference was observed when the mean AP spinal canal diameters for the various spinal levels were compared. The AP canal diameters of the present study were found to be smaller than those of male Caucasians (Tatarek 2005; Lee et al., 2007; Chazono et al., 2012), but were comparable to those of Asian males (Hashimoto and Tak, 1977; Lee et al., 1994; Toki et al., 2021; Griffith and Lee 2024).

Comparing the results of the present study to those of Tatarek, (2005) and Lee et al. (2007) who measured the AP spinal canals diameter of vertebrae from persons of African-American ancestry, it was observed that, the mean AP canal diameters recorded in those studies were larger than those of the present study. It is well documented that the majority of African-

There were 2 cervical spine segment that were observed to have multiple stenotic canals (Table 3).

One cervical spine segment had 3 relatively narrow spinal canals at C3, C4 and C5 spinal levels, while the other cervical spine segment had 4 vertebrae that showed some degree of narrowing. There was a narrow spinal canal at C3 and 3 relatively narrow spinal canals at C4-6. The highest incidence of narrowing narrow and relatively narrow) was observed in the C5 vertebra (Table 2)

Americans trace their roots to the tribes and ethnic group of the West African sub-region where present-day Ghana is located. It is therefore worthy of note that the AP diameters of the present study were dissimilar to those reported in male African-American (Tatarek, 2005; Lee et al., 2007).

This suggests that, even though genetic may plays a key role determining the size of cervical spinal canals, (Eisenstein, 1983; Tatarek, 2005) genetics alone cannot be used explain the similarities or variations observed within races and ethnicities. It has been long suggested that environmental factors may contribute significantly to this phenomenon (Tatarek, 2005). Nutrition, socio-economic status and the endemicity of certain diseases have all been found to influence bone growth and development (Lewis et al., 2002; Schmeling et al., 2006; Dembetembe and Morris 2012; Brown et al., 2020a; Brown et al., 2020b).

These factors may better explain why people of common ancestry, separated geographically and living under different socio-economic conditions may exhibit these differences. The findings from this study suggests that cut off values for diagnosing CS must not only be race specific but its application must be limited by geographical location. Thus, cut off values that are applicable to a group of people in one geographical location cannot to be applied to another group in another location because of shared ancestry or race."

The percentage of narrow cervical spinal canals was 1.82%, while relatively narrow spinal canals was 10.0%. It therefore, appears that, relatively narrow canals make up the greater proportion of stenotic spinal canals in the Ghanaian males. An observation which is similar to those of Tatarek (2005). It has also been reported that narrow spinal canals occur more frequently in C2-C4 compared to C5-C7 vertebrae (Tatarek, 2005), an assertion that is supported by the findings of the present study.

Across the various spinal levels, the cut-off values for relatively narrow ranged from 8.62-12.36mm. The cut off for narrow spinal canals was <9.30 mm at the C3 vertebral level, <8.62 mm at C4, <10.19 mm at C5, <10.93 mm at C6 and <10.86mm at the C7 spinal level. These differences in cut-off values suggest that in diagnosing CS using AP diameter of the spinal canal, clinicians should not lose sight of the spinal level under consideration as this influences the cut off values.

Two cervical spinal columns were found to have multiple stenotic canals. The multiple stenosis consisted of either all relatively narrow canals or a combination of relatively narrow and narrow

canals. There was no specimen that had multiple stenotic canals comprised entirely of narrow cervical spinal canals. Thus, the occurrence of multiple narrow spinal canals in a single spinal column appears to be uncommon.

Individuals with larger canals are known to be more protected from cervical injury, while those with smaller cervical spinal canals correlate significantly with neurologic injury (Eismont *et al.*, 1984; Tatarek 2005). The findings of this study will therefore not only guide clinician to diagnose CS, but perhaps even more importantly, it may help them to identify individuals at risk of cervical spinal injury due to the presence of smaller cervical spinal canals. Such individuals can be given appropriate advice with regards to participation in activities such as contact or combative sport and in so doing help avert serious injuries that were otherwise avoidable.

Although knowledge on CS has increased, it is still not clear as to what degree of narrowing will result in clinically detectable symptoms nor is there much understanding on the role that multiple stenotic vertebrae play in the onset, severity and the progression of symptoms. The future direction of CS studies must therefore be focused in these areas.

Conclusion

In the present study 11.8% of cervical vertebrae showed some degree of narrowing. The mean AP diameters of the spinal canals in the present study were found to be smaller than those reported in Caucasians and African American males but were comparable to Asian males. The findings of this study go to support the assertion that there can be no universal cut-off value for diagnosing CS when the AP diameter of cervical spinal canal is used as the means of assessment. In addition, criteria that are developed for diagnosing CS in a particular population cannot be applied to another population simply because of shared ancestry. It is recommended that clinician develop cut-off values for diagnosing CS that take into account race, geographical location and cervical spinal levels.

Conflict of Interest: The Author declare no conflict of interest

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