Full length article

Roentgenographic and computerized tomography based morphometric analysis of cervical spinal canal diameters to establish normative measurements in an Indian population

Kapil A. Pawar, Arya S. Mishra*, Gokul Bandagi, Sudhir K. Srivastava

Department of Orthopaedics, Seth GS Medical College and KEM Hospital, Mumbai, India

ARTICLE INFO

Article history:

Received 15 August 2016

Received in revised form 30 October 2016

Accepted 11 January 2017

Available online 20 January 2017

Keywords:

Cervical spinal canal

Cervical canal stenosis

Cervical spondylotic myelopathy

ABSTRACT

Compressive cervical myelopathy secondary to degenerative changes in the cervical spine is a common cause of neurologic morbidity in the elderly. Identification of canal stenosis and addressing it surgically in addition to the obvious compressive lesions is essential to obtain satisfactory results. We attempt to define the sagittal and transverse diameters in a normal adult population presenting at our centre with head injuries. We found that the values were lower than those reported in comparable studies for a western population, and also that the dimensions in women are significantly lower than in men.

© 2017

1. Introduction

Cervical compressive myelopathy secondary to degenerative (spondylotic) changes is a common cause of neurologic morbidity in elderly patients. The symptoms can also arise earlier, in a younger population, if there is any congenital narrowing of the canal, as the canal can be compromised with relatively minor spondylotic changes which appear earlier in the natural history.¹ However, the presence of spondylotic changes being an universal age-related occurrence, it may be unclear as to whether the myelopathic changes should be attributed to the reduction in bony canal dimensions and the cord compression resulting from it or not. Also it is necessary to know whether there is a component of canal stenosis over and above the obvious compressive lesions such as a disc or osteophyte. We have attempted to define the normal diameters of the bony canal (sagittal and transverse) using radiographs and computerized tomography scans in skeletally mature adults, as normative data for the same are not available in the literature for an Indian population.

2. Material and methods

We have used cervical spine radiographs and computerized tomography (CT) scans of 100 consecutive patients older than 18 years of age with head injury and without cervical spine injury

admitted to our Centre. Patients with pre-existing cervical spine malformations, surgery or rheumatoid arthritis were excluded. The lateral cervical spine radiograph is part of the primary survey in ATLS® protocol for all poly trauma patients.² The cervical spine is included as part of Head CT-scan protocols in case of a head injury at our institute. As such, patients were not exposed to any additional radiation for the purpose of this study.

Permission for use of the scans was obtained from the patients or relatives, based on the status of consciousness of the patient. The height of the patients was taken from medical records.

The radiographs were taken with a spherical marker to control for magnification, with the beam centered on C4 as defined by the upper border of the thyroid cartilage, from a source 6 feet (72 in.; 180 cm) away. The X-rays and CT scans were analyzed using OsiriX ver 5.6 (Pixmeo, Geneva, Switzerland). The Antero-posterior diameter was measured at each level on the radiograph from the midpoint of the posterior cortex of each vertebra to the nearest point on the spino-laminar line (Fig. 1). The antero-posterior and transverse diameter in the CT scans was measured on an axial cut taken parallel to the superior end-plate through the mid-point of the posterior cortex as defined on a sagittal section. The antero-posterior diameter was measured from a point on the posterior cortex to a point on the posterior elements defined by the line bisecting the interpedicular line. The lateral diameter was measured as the largest perpendicular to this line within the confines of the canal (Fig. 2). As the points of reference detailed above are variable and subject to observer bias, two authors (KAP and GB) measured each parameter independently. Further, each author took two readings (not one after the other). So, we had four

* Corresponding author.

E-mail address: aryasuman@gmail.com (A.S. Mishra).

Fig. 1. Sagittal Cervical canal diameter on Lateral radiograph. The magnification control is seen at left lower corner.

Fig. 2. Measuring sagittal and transverse diameters on CT scan. The point and direction of the axial section is first defined on the sagittal section (a), the diameters are then measured on the axial section as shown (b).

values for each parameter, the mean of which was admitted for analysis, thereby minimizing observer bias.

The values collected were then analyzed using GraphPad Instat ver 3.4, and trends were evaluated.

3. Results

We collected data from 100 consecutive cases that satisfied our inclusion criteria. 65 men and 35 women were included. We found there to be no correlation between height and cervical spine

diameters among the patients studied (using Pearson's correlation coefficient, $r = 0.0152$, $p = 0.523$). A statistically significant correlation was seen between the antero-posterior diameters measured on lateral radiographs and CT scans (Using Pearson's correlation coefficient, intermediate to strong correlation was found with a p value less than 0.005, as summarized in Table 1). Thus, well made lateral radiographs can be used alone if CT scan is not available. However, in a spondylotic cervical spine accuracy can be poor due to poor visualization of canal osteophytes and a CT scan is still recommended.

Table 1

Correlation between X-ray and CT Antero-posterior diameters.

Characteristics	Correlation coefficient (r)	P value
At C1	0.7838	<0.0001
At C2	0.7772	<0.0001
At C3	0.5554	<0.0001
At C4	0.7022	<0.0001
At C5	0.3624	0.0004
At C6	0.6743	<0.0001
At C7	0.7211	<0.0001

Using Pearson's correlation coefficient, P value < 0.05 is considered significant. For 'r' <0.25 = weak correlation; 0.25–0.75 = Intermediate correlation; >0.75 = Strong correlation.

Table 2

Vertebrae wise difference in X Ray AP view measurements in both genders.

Vertebrae	Gender	X Ray AP (mean ± SD)	(95% CI)	P value
C1	Male	22.17 ± 3.13	21.40–22.95	<0.0001
	Female	16.93 ± 2.77	15.98–17.89	
C2	Male	21.60 ± 2.52	20.97–22.23	<0.0001
	Female	17.31 ± 1.80	16.69–17.93	
C3	Male	17.40 ± 2.00	16.90–17.89	<0.0001
	Female	14.45 ± 1.10	14.07–14.83	
C4	Male	16.60 ± 2.79	15.92–17.30	0.0003
	Female	14.67 ± 1.65	14.11–15.24	
C5	Male	17.55 ± 2.38	16.97–18.14	<0.0001
	Female	13.36 ± 0.87	13.06–13.66	
C6	Male	17.57 ± 2.18	17.02–18.11	<0.0001
	Female	14.22 ± 0.99	13.88–14.56	
C7	Male	17.67 ± 1.53	17.30–18.05	<0.0001
	Female	14.85 ± 1.20	14.44–15.27	

Using unpaired *t*-test, *p* < 0.05 is considered significant.

There was a significant difference between the genders in both antero-posterior and lateral diameters at all vertebral levels on both X-Ray and CT scans (using unpaired *t*-test, results summarized in Tables 2–4), which suggests a need for separate definitions of the normal range in men and women. Using a single population cut-off of normal can lead to erroneous attribution of a compressive aetiology to clinically diagnosed myelopathy under investigation in women.

Table 3

Vertebrae wise difference in CT AP view measurements in both genders.

Vertebrae	Gender	CT AP (mean ± SD)	(95% CI)	P value
C1	Male	18.55 ± 2.77	17.87–19.24	<0.0001
	Female	14.25 ± 2.66	13.34–15.17	
C2	Male	17.21 ± 2.21	16.66–17.75	<0.0001
	Female	13.98 ± 1.53	13.46–14.51	
C3	Male	13.10 ± 1.15	12.82–13.39	<0.0001
	Female	11.78 ± 1.12	11.40–12.18	
C4	Male	12.84 ± 1.68	12.43–13.27	0.1479
	Female	12.36 ± 1.36	11.90–12.83	
C5	Male	13.19 ± 1.40	12.84–13.54	0.0006
	Female	12.23 ± 1.05	11.87–12.60	
C6	Male	13.70 ± 0.77	13.52–13.90	<0.0001
	Female	11.84 ± 0.98	11.50–12.18	
C7	Male	14.20 ± 1.02	13.94–14.46	<0.0001
	Female	12.13 ± 1.08	12.64–13.40	

Using unpaired *t*-test, *p* < 0.05 is considered significant.

Table 4

Vertebrae wise difference in CT Lateral view measurements in both genders.

Vertebrae	Gender	CT Lat (mean ± SD)	(95% CI)	P value
C1	Male	27.48 ± 1.76	27.04–27.91	<0.0001
	Female	24.66 ± 1.81	24.04–25.29	
C2	Male	23.08 ± 1.22	22.78–23.38	<0.0001
	Female	21.73 ± 2.00	21.05–22.43	
C3	Male	22.41 ± 2.65	21.76–23.08	0.0004
	Female	20.57 ± 1.79	19.96–21.19	
C4	Male	24.75 ± 1.61	24.35–25.15	<0.0001
	Female	21.63 ± 1.67	21.06–22.21	
C5	Male	24.87 ± 1.32	24.55–25.21	<0.0001
	Female	22.06 ± 1.25	21.62–22.49	
C6	Male	25.03 ± 1.46	24.67–25.39	<0.0001
	Female	22.05 ± 1.57	21.51–22.59	
C7	Male	24.83 ± 2.45	24.22–25.43	<0.0001
	Female	21.72 ± 1.09	21.35–22.10	

Using unpaired *t*-test, *p* < 0.05 is considered significant.

The antero-posterior diameters at C1 and C2 levels were significantly different from each other and the sub-axial cervical spine (C3–C7), while there was no significant difference between the different levels in the sub-axial spine (using RMANOVA, *p* value of less than 0.05 was considered significant). This suggests that one single cut-off value can be applied for the entire sub-axial spinal canal, and different values are needed at C1 and C2. Similar analysis of the transverse diameters suggests a single value for C1 and another for the rest of the levels.

In keeping with our observations, our measurements are summarised separately for both genders in Tables 5–6 and Figures 3–4. Single values applicable to multiple vertebral levels as explained above are mentioned in bold in the footnotes.

Table 5

Vertebrae level wise values in males (in mm).

Vertebrae	X ray sagittal (95%CI)	CT sagittal (95%CI)	CT Lat (95%CI)
C1	22.2 (21.4–23.0)	18.6 (17.9–19.2)	27.5 (27.0–27.9)
C2	21.6 (21.0–22.2)	17.2 (16.7–17.8)	23.0 (22.8–23.4)
C3	17.4 (16.9–17.9)	13.1 (12.8–13.4)	22.4 (21.8–23.1)
C4	16.6 (15.9–17.3)	12.8 (12.4–13.3)	24.8 (24.4–25.2)
C5	17.6 (17.0–18.1)	13.2 (12.8–13.5)	24.9 (24.6–25.2)
C6	17.6 (17.0–18.1)	13.7 (13.5–13.9)	25.0 (24.7–25.4)
C7	17.7 (17.3–18.0)	14.2 (13.9–14.5)	24.8 (24.2–25.4)

Using RMANOVA:

C3–C7 showed no significant difference among them on CT sagittal with *p*-value < 0.05. Average for C3–C7 = **13.4 mm**

C2–C7 showed no significant difference among them in CT lateral diameters. Average for C2–C7 = **24.2 mm**.

Table 6

Vertebrae level wise values in females (in mm).

Vertebrae	X ray sagittal (95% CI)	CT sagittal (95% CI)	CT transverse (95% CI)
C1	16.9 (16.0–17.9)	14.2 (13.3–15.1)	24.7 (24.0–25.3)
C2	17.3 (16.7–17.9)	14.0 (13.5–14.5)	21.7 (21.1–22.4)
C3	14.5 (14.1–14.8)	11.8 (11.4–12.2)	20.6 (20.0–21.2)
C4	14.7 (14.1–15.2)	12.4 (11.9–12.8)	21.6 (21.1–22.2)
C5	13.4 (13.1–13.7)	12.2 (11.9–12.6)	22.1 (21.6–22.5)
C6	14.2 (13.9–14.6)	11.8 (11.5–12.2)	22.1 (21.5–22.6)
C7	14.9 (14.4–15.3)	12.1 (12.6–13.4)	21.7 (21.4–22.1)

Using RMANOVA:

C3–C7 showed no significant difference among them on CT sagittal with p-value < 0.05. Average for C3–C7 = **12.0 mm** (CT).C2–C7 showed no significant difference among them in CT lateral diameters. Average for C2–C7 = **21.6 mm**.

4. Discussion

The diagnosis of cervical canal stenosis in an established case of compressive spondylotic cervical myelopathy (SCM) has been a subject of much research. Focal changes arising due to degenerative disease, like disc prolapse and osteophytes, may seem to be the clear culprit, but they may actually be added sources of compression superimposed on a generalized narrowing of the canal. This could lead to poor results if surgery is targeted only at the focal change leaving the background stenosis unaddressed.^{1,3} Therefore, recognition of Cervical stenosis at other levels without obvious changes has critical importance.

With this background, many authors have attempted to find methods to identify bony canal stenosis using radiographic techniques. Initial studies used standardized X-ray techniques to define the normal sagittal diameter.^{4–10} However they were found to be inaccurate, being subject to problems of magnification error. In search of a means to address this difficulty, Pavlov et al. in 1987 defined a ratio of the canal sagittal diameter to the antero-posterior mid cervical body width.¹¹ The principle was that the body width controlled for the magnification in the ratio, and the measure obtained represented the actual canal diameters more accurately. They also proved that lower Pavlov ratios were associated with spondylotic cervical myelopathy. Their findings have since been reiterated by various authors.^{12,13}

Criticism of this method is chiefly based on the fact that the variations in body size can offset its usefulness as a surrogate measure of the actual diameter. Not only is population variability a source of error, but also deformities of the vertebral body and the

Fig. 3. Mean Radiographic values (Men).

Fig. 4. Mean Radiologic values (Women).

increase in body diameter due to degenerative processes in the scenario of advanced spondylosis usually seen in patients with CSM.¹⁴ It is possible that the correlation of low Torg-Pavlov ratio with CSM arises from this second source rather than an actual canal compromise. Also, availability of modern imaging like CT scan and MRI, which can directly and accurately measure the canal diameter, makes the use of this ratio obsolete. In a CT based study, Blackley et al. have shown that neither the Pavlov ratio, nor any other ratio correlates with the actual measured diameter.¹⁴ Thus the actual diameter measured on CT scan is a better predictor of Canal stenosis. Also, in an older study by Stanley et al., a correlation between decreased CT scan sagittal diameter and CSM was shown.¹⁵

We have therefore attempted to define the diameters on X-Ray and CT scan in a normal patient group of 100 patients, as normative data for an Indian population is unavailable. In the X-ray we have used a known radiopaque marker placed on the film to control for magnification and used it to scale our measurements. We now discuss the chief trends identified in our study.

We did not find any correlation between the height of the individuals and the measured diameters, which shows that the cervical spine diameters are probably not related to other anthropometric parameters related to build.

In X-ray studies, the sagittal diameter has been measured by Wholey et al.⁵ at 18.4 mm and Burrows⁷ at 17.7 mm in a western population. The value obtained by us of 16.3 mm is, respectively, 2.1 mm and 1.3 mm smaller. It is closer to that obtained in a Southeast Asian population by Soo and Sachdev⁹ (16.2 mm) and Oon¹⁰ (15.3 mm).

In the study by Stanley et al.,¹⁵ the average sagittal diameter was 14.3 mm and transverse diameter 23.9 mm. From our study, the averages for sagittal diameter were lower at 12.9 mm (combined), 13.4 mm (males) and 12 mm (females). The average transverse diameter was comparable for males at 24.2 mm, but much lower for females at 21.6 mm. This shows that normative data for an Indian population will most likely be significantly different from western data, and hence must be quantified by more studies. However, the cutoff for canal stenosis defined at 10 mm by Stanley et al. appears valid as none of the subjects studied had a value below this at any level. This corresponds to an average cord diameter of 9.3 mm as described by them using CT myelography.¹⁵

The difference we found between males and females, for both sagittal and transverse canal diameters, at all levels (except the C4 sagittal, on both X-ray and CT) has never been reported previously. It shows that a single value cannot be used for both sexes, and separate cutoffs should be determined.

Finally, a small sample size prevents generalization of the standard deviation measure to the population, and using the mean-2SD value as a cutoff from this data is not statistically tenable. A larger study will be able to offset this limitation.

5. Conclusion

The sagittal and transverse diameters of the Cervical spinal canal on both X-rays and CT scans in our study is lower than that reported in the western population, suggesting the need for separate normative data in an Indian population. We have also demonstrated a significantly lower figure in women than men at all

vertebral levels, which demonstrates the need for separate figures for male and female populations.

Conflict of interest

None.

References

1. Kato S, Fehlings M. Degenerative cervical myelopathy. *Curr Rev Musculoskelet Med*. 2016;9(September (3)):263–271.
2. Kool DR, Blickman JG. Advanced Trauma Life Support®. ABCDE from a radiological point of view. *Emerg Radiol*. 2007;14(3):135–141.
3. Nouri A, Tetreault L, Singh A, Karadimas SK, Fehlings MG. Degenerative cervical myelopathy: epidemiology, genetics, and pathogenesis. *Spine (Phila Pa 1976)*. 2015;40(June (12)):E675–E693.
4. Wolf BS, Khilnani M, Malis L. The sagittal diameter of the bony cervical spinal canal and its significance in cervical spondylosis. *J Mt Sinai Hosp N Y*. 1956;23(May–June (3)):283–292.
5. Wholey MH, Bruwer AJ, Baker Jr. HL Jr.. The lateral roentgenogram of the neck; with comments on the atlanto-odontoid-basion relationship. *Radiology*. 1958;71(September (3)):350–356.
6. Chrispin AR, Lees F. The spinal canal in cervical spondylosis. *J Neurol Neurosurg Psychiatry*. 1963;26(2):166–170.
7. Burrows EH. The sagittal diameter of the spinal canal in cervical spondylosis. *Clin Radiol*. 1963;14(January):77–86.
8. Boijesen E. The cervical spinal canal in intraspinal expansive processes. *Acta Radiol*. 1954;42(August (2)):101–115.
9. Soo YS, Sachdev AS. Calcification in the posterior longitudinal ligament as a cause of cervical myelopathy. *Med J Aust*. 1971;1(April (14)):743–744.
10. Oon CL. The sagittal diameter of the cervical canal. *Singap Med J*. 1974;15(September (3)):218–222.
11. Pavlov H, Torg JS, Robie B, Jahre C. Cervical spinal stenosis: determination with vertebral body ratio method. *Radiology*. 1987;164(September (3)):771–775.
12. Suk K-S, Kim K-T, Lee J-H, Lee S-H, Kim J-S, Kim J-Y. Reevaluation of the Pavlov ratio in patients with cervical myelopathy. *Clin Orthop Surg*. 2009;1(1):6–10.
13. Yue WM, Tan SB, Tan MH, Koh DC, Tan CT. The Torg-Pavlov ratio in cervical spondylotic myelopathy: a comparative study between patients with cervical spondylotic myelopathy and a nonspondylotic, nonmyelopathic population. *Spine (Phila Pa 1976)*. 2001;26(August (16)):1760–1764.
14. Blackley HR, Plank LD, Robertson PA. Determining the sagittal dimensions of the canal of the cervical spine. The reliability of ratios of anatomical measurements. *J Bone Jt Surg Br*. 1999;81(January (1)):110–112.
15. Stanley JH, Schabel SI, Frey GD, Hungerford GD. Quantitative analysis of the cervical spinal canal by computed tomography. *Neuroradiology*. 1986;28(2):139–143.