Dimensions of the cervical spinal canal in the South African negroid population

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Introduction

Although spinal stenosis has been recognized for many years as a clinical diagnosis, it has yet to be exactly defined and agreed upon. This lack of definition leads to difficulties in comparing and interpreting studies of the prevalence, incidence and treatment thereof[1]. This could in part be due to differences in spinal canal dimensions that exist between population groups as documented by various authors[2]

A midsagittal spinal canal diameter of less than 12mm is believed to be indicative of cervical spinal stenosis[3]. Significant variation in the dimensions of the cervical spinal canal precludes the usage of universal definitions to determine the presence of spinal stenosis in individuals. These definitions should rather be based on sex and descent[4].

The question arises as to whether standards applied to other population groups can be applied to the South African black population to define what is normal and abnormal in terms of dimensions of the cervical spinal canal, especially when considering that statistically significant differences have been found to exist between population groups in various other studies[2,5,6,7].

Pathology and stenosis of the cervical area is mostly in the sagittal plane. However, a narrow sagittal spinal canal diameter by itself might not indicate a significant decrease in the area of the canal. The Pavlov ratio maintains that the sagittal diameter of the canal in relation to the corresponding vertebral body is a reliable indicator of cervical spinal stenosis[8]. The ratio is close to 1 in normal individuals and indicative of stenosis if it is less than 0.82.

However, studies done on different population groups yielded contradicting results in terms of the validity of the application of the ratio. It is currently used as a universal indicator of cervical spinal canal stenosis in spite of the fact that differences between race and sex have been reported[9].

The shape of the canal, occurrence of osteophytes, and ossification of the posterior longitudinal ligament (OPLL) are all contributing factors to stenosis.

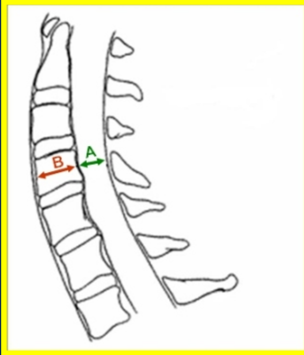


Figure 1. The Pavlov ratio is calculated by dividing the sagittal measurement of the canal with that of the vertebral body

Aims

1. Use skeletal material and CT scans to measure and/or determine the:
   a. Midsagittal diameter of the vertebral canal and corresponding vertebral body
   b. Pavlov ratio for each vertebral level (C3 to C7)
   c. Morphometric dimensions of the vertebral canal to determine the shape
   d. Occurrence of osteophytes
   e. Occurrence of ossification of the posterior longitudinal ligament (OPLL)

2. Use the results obtained to discover:
   a. If skeletal measurements correspond with those from CT scans
   b. If a difference exists between the sexes
   c. What is the affect of age
   d. Where is the area of greatest stenosis
   e. If there is a correlation between the South African black population and other populations

Material and Methods

The transverse and sagittal dimensions of the cervical vertebral canal and sagittal dimensions of the vertebral bodies from C3 to C7 were measured with a digital micrometer (accuracy: 0.01mm) on the skeletal remains of 179 individuals (90 males and 89 females, divided into 3 age categories of 30-45; 46-60 and 61-75 years), obtained from the Pretoria Bone Collection at the University of Pretoria and the Raymond A. Dart Collection at the University of the Witwatersrand.

These were compared to measurements taken from CT-scans of 55 individuals divided into the same categories. The CT-scans were measured using the ViewTec MedView 1.0.0.2 software program (accuracy of 0.01mm).

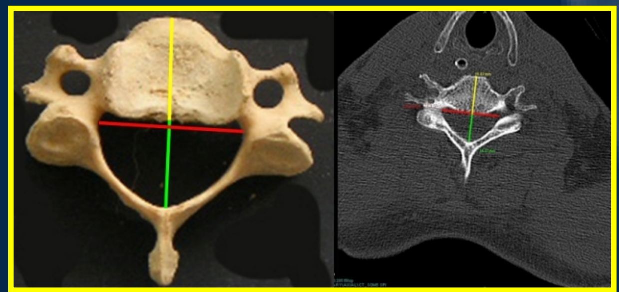


Figure 2. Measurements on skeletal material and CT scans

Photographs were taken of the vertebrae and analyzed with the following programs:

- tpsDig used for digitizing landmarks
- tpsSplin used to compare specimens by displaying a transformation grid
- tpsRelw used to perform relative warp analysis
- IMP: TwoGroup6 this determines pairwise significant differences in shapes between groups using Goodall's F-test and Hotelling's T2 test.

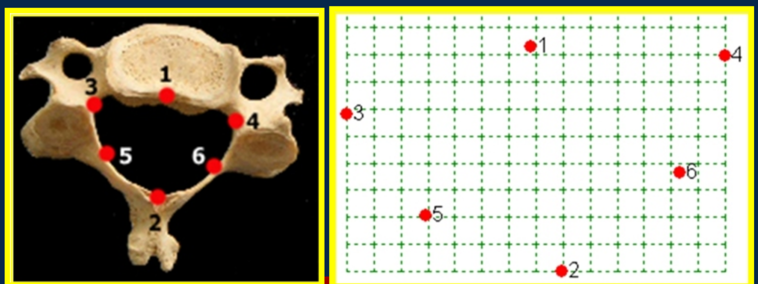


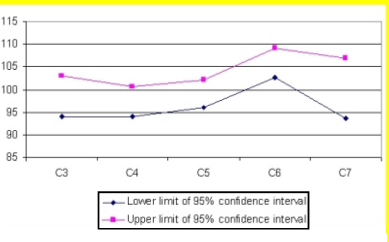
Figure 3. Determination of points on vertebra and resulting thin plate spline

Skeletal material of 107 vertebral columns was used to determine the occurrence and distribution as well as severity of osteophytes on the laminae and posterior aspect of the vertebral bodies of C3 to C7. The incidence of ossification of the posterior longitudinal ligament (OPLL) was also investigated in the same cervical region.

Results

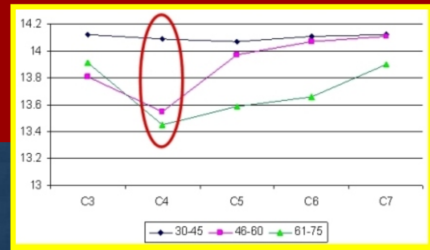
1. There was no significant difference between measurements taken on skeletal material and CT-scans.

95% Confidence interval values for comparison of measurements on CT-scansrelative to measurements of skeletal material

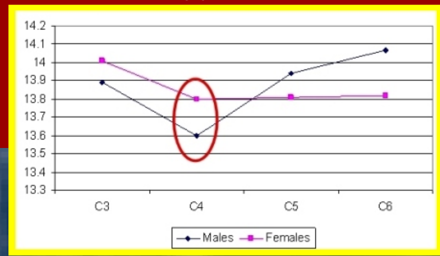


2. C4 shows the greatest decrease in the age groups of 46-60 and 61-75. The vertebral canal is larger in males (mean=13.96mm) than in females (Mean=13.84mm).

Sagittal cervical vertebral canal diameter indicating age differentiation in the skeletal study population

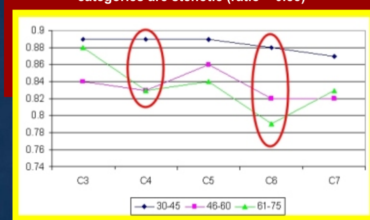


Sagittal cervical vertebral canal diameter indicating sex differentiation in the skeletal study population

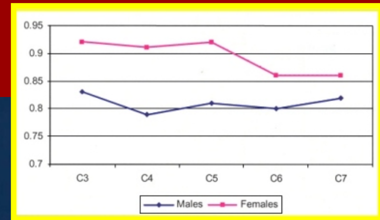


3. The Pavlov ratio is larger for females (mean = 0.89) than males (mean = 0.81) and the ratio seems to overestimate the occurrence of spinal stenosis in this population group, as almost all individuals older than 46 years were classified as stenotic according to this.

Pavlov's ratio for cervical vertebral canal indicating age differentiation in the skeletal study population. Significant differences exist at the levels of C4 (P=0.03) and C6 (P=0.01) between the age catagories. The ratio indicates that almost all vertebrae in the oldest 2 categories are stenotic (ratio < 0.85)

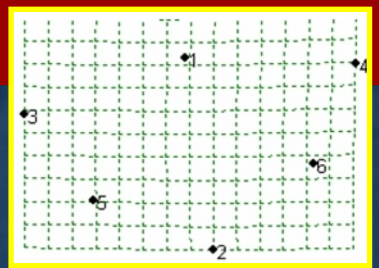


Pavlov's ratio for cervical spinal canal indicating sexdifferentiation in the skeletal study population

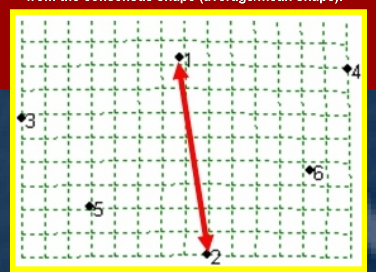


4. The digital morphometry disclosed a significant difference between males and females. In males the canal is congenitally triangular, whereas in females the canal assumes a more "safe" rounded shape.

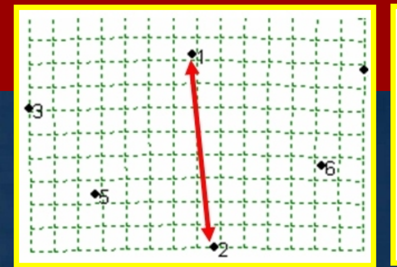
Males
Almost no bending of the grid is observed,indicating that the shape of the cervical spinal canal in males is closest to that of the consensus shape. Landmark 1 is closer to landmark 2 than observed in females



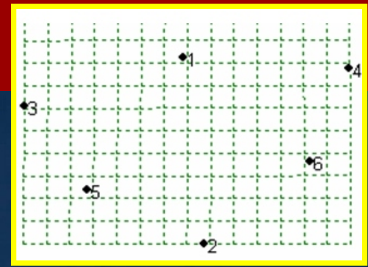
Females
Relative to the consensus shape, landmark 1 is situated further away from landmark 2 in females. This clearly indicates that the spinal canal sagittal diameter is larger in females than in males. The bending of the grid indicates deviation from the consensus shape (average/mean shape).



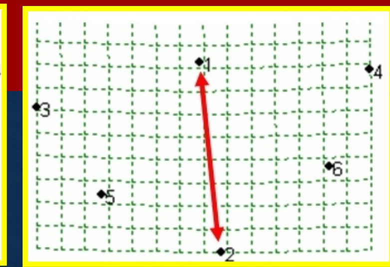
Age group 30-45 years
Relative to the consensus shape, in the youngest age group landmark 1 is situated further away from landmark 2. This indicates that the spinalcanal sagittal diameter is larger in individuals 30-45 years,than in the consensus shape



Age group 46-60 years
Almost no bending of the grid is observed, indicating that this age group's shape is closest to that of the consensus shape. Landmark 1 is closer to landmark 2 than observed in the younger age category (30-45), indicating a smaller sagittal diameter of the cervical spinal canal.



Age group 61-75 years
Relative to the consensus, landmark 1 is closer to landmark 2 indicating a decreased sagittal canal diameter. It is in this age category that the sagittal diameter is the smallest.

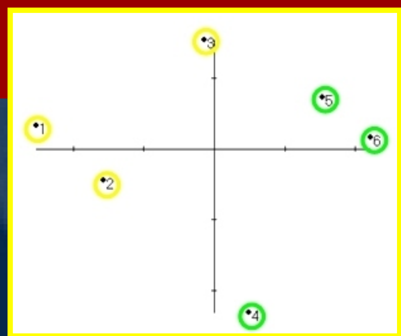


Relative warp ordination plot comparing males and females from all age categories

Categories

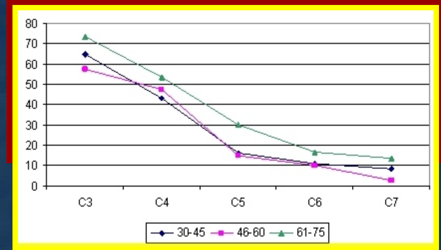
1. Females age 30-45
2. Females age 46-60
3. Females age 61-75
4. Males age 30-45
5. Males age 46-60
6. Males age 61-75

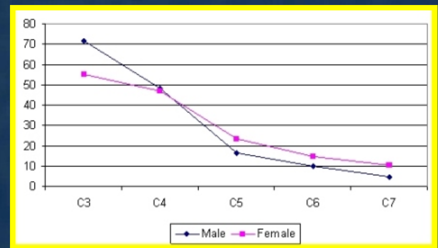
All females (points 1, 2 and 3) are situated to the left of the Y-axis in this graph whereas all males (points 5, 6 and 7) are All located to the right of the Y-axis of the graph.



6. Osteophyte occurrence within the cervical spinal canal was similar for males and females, while OPLL was a frequent finding. This was most pronounced at the level of C3 and steadily declined towards C7 (C3 = 64.5%; C4 = 47.7%; C5 = 21%; C6 = 12.2%; C7 = 7.5%)

The graph below illustrate that, although there is an increase in the occurrence of osteophytes with advancing years, it is almost uniform starting at C3 (highest) and ending at C7 (lowest). The graph at the bottom shows that there is a higher incidence of osteophytes in males than females, especially at C3, but otherwise very similar throughout





Conclusion

It is questionable whether the Pavlov ratio[8] is at all reliable as a predictive measure of stenosis within the South African black population. The dimensions of the canal indicate that in no age category, or even when differentiating between males and females regardless of age, the canal can be considered stenotic, as all means are well above the 12mm dividing point. Due to the nature of the measurements used to calculate the ratio, the difference in shape of the canal between the sexes may also contribute to accounting for the differences observed in the ratio. The use of a set dimension, such as the universal 12mm dividing point between normal and stenotic canals could be considered more reliable.

Because the vertebral body naturally protrudes further into the spinal canal in males than in females causing the male canal to assume a triangular shape (rather than the rounder shape of the canal in females) the ratio will be affected markedly in males with even the slightest manifestation of pathology. This could possibly explain why the ratio defines all males within this study population as having stenotic spinal canals with the ratio at all levels below 0.85, whilst the females are all classified as normal with a ratio above 0.85.

The reliability of universal indicators for the diagnosis of cervical spinal stenosis were compared, discussed and found to be inaccurate in terms of application on the South African black population. This study has shown that both ethnicity and sex have to be considered when diagnosing cervical spinal stenosis within this population group, hence the need for clear and reliable dimensional guidelines and indicators.

The high correlation between the skeletal and CT scan measurements indicates that the latter offers an ideal method for detecting cervical spinal stenosis.

Discussion

The shape of the spinal canal is generally defined as: trefoil, which lends itself to cause radicular disturbances; triangular, manifesting neurological symptoms such as radicular disturbances and intermittent claudication; round, which is considered to be "safe" and causes no neurological deficits; and intermediate. A predisposition to spinal cord injury due to trauma depends more on the shape of the canal rather than on the volume of space in the canal[9].

Clear dimensions were established and found to be different from other study populations, but for the first time, the shape of the cervical spinal canal has been morphometrically described and comparisons drawn between males and females. A correlation has now been established between the sex related differences in the shape of the canal and possible symptomatic outfall. Size differences should however be discussed in light of the shape of the cervical spinal canal in both sexes. Although the relative warp analyses reveal that the consensus shapes of males and females appear similar in that the basic shape is triangular, there are statistically significant differences between the sexes throughout all the age groups. The female canal has a more rounded shape whereas the male canal is more triangular.

It is important to note that any change in the dimensions of the canal in the anteroposterior direction due to various pathological conditions that include, but is not limited to, osteophytosis and ossification of the posterior longitudinal ligament (OPLL) on the posterior aspect of the vertebral body, will result in the triangular male canal assuming a trefoil like shape, possibly impinging the spinal cord, whereas in females, manifesting with the same degree of pathology in the same dimension, the rounder canal will assume a still "safe" triangular shape.

In males, canal shape changes can be observed much earlier (after age 45) than in females where the changes only start after age 60. The midsagittal diameter of the cervical spinal canal decreases with age with C4 being the level affected most by aging. The dimensions of C3 and C4 change dramatically after age 45 whereas changes in C5 to C7 only appear after age 60.

Geometric morphometry indicate that the shape of the cervical spinal canal significantly changes with age throughout all age groups and across both sexes. By studying the occurrence and incidence of osteophytosis and OPLL we can now account for possible changes in the shape of the canal.

No statistically significant differences could be observed between measurements taken on skeletal material and CT-scans. This is confirmed by very high 95% confidence intervals (values between 96 and 104) in spite of the fact that measurements on CT-scans occasionally proved to be difficult due to lack of clear definition of borders on the CT-scans.

It has been shown that the sagittal diameter of the cervical spinal canal in the South African black population is consistently smaller than that of the Japanese population. This occurs across all the vertebrae by more than 1,5mm, and is similar to the Korean population.

This study has proven conclusively and with a large study population that there are statistically significant differences between cervical spinal canal dimensions of males and females and among the age groups. This has been confirmed by studying changing shapes of the cervical spinal canal between sexes and age groups and, with the aid of geometric morphometry, visualizing these changing dimensions.

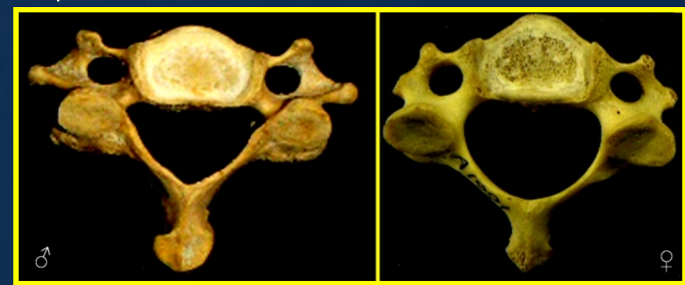


Figure 4. Males have a triangular-shaped cervical canal, while females possess a more rounded shape

Figure 5. When osteophytes are present, the triangular-shaped canal of males assumes a trefoil-like shape that is stenotic, while the more rounded shape of females becomes triangular, but is still "safe"

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