Comparison of digital radiography and computed tomography morphometric profiles of cervical spinal canal vertebrae

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Comparison of digital radiography and computed tomography morphometric profiles of cervical spinal canal vertebrae

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Abstract. The study aim was to determine the size of the normal cervical spinal canal on plain film and to correlate it with its size on computed tomography (CT) to make a diagnostic model of spinal stenosis based on plain film radiography. The study included 51 subjects who had no spinal deformities (age range, 16–60 years). We measured the sagittal and interpedicular diameters of the cervical canal by plain film and by CT. If the CT result was normal, anteroposterior and lateral x-rays of the cervical spine were taken in the neutral position at a 100-cm focal-film distance. SPSS statistical software was used to measure and analyze the sagittal diameter of the cervical canal and interpedicular diameters. The mean sagittal diameter of the cervical canal ranged from 16 mm (C4) to 18 mm (C6). The mean interpedicular diameter ranged from 25.2 mm (C3) to 26.2 mm (C6). There were significant differences in the sagittal and interpedicular diameters between sex, height, and weight groups. There was a strong correlation between the radiographic and CT sagittal canal diameters but a weak one between the interpedicular diameters. The plain film/CT sagittal canal diameter correlation coefficients were 0.73 (C3), 0.75 (C4–C6), and 0.77 (C7).

1. Introduction

Various measurements have been used to determine the dimensions of the spinal canal; however, no consensus has been reached on which is best. Mid-sagittal diameter, interpedicular distance, cross-sectional area, and the canal/body ratio (Torg's ratio) are important radiological parameters. Bolender et al. (1985) stated that myelographic computed tomography CT was effective for evaluating the diameter of the spinal canal [1,2]. Boijsen (1954) first recorded radiographic measurements of the sagittal diameter of the cervical canal. Elsberg and Dyke (1934) published interpedicular normal plain film anteroposterior (AP) x-ray radiographic values for the specified distance in adult spines [1,3].

Plain film radiography is the standard radiological modality used in all hospitals in Indonesia, and the costs are relatively low. In the diagnosis of spinal canal stenosis, CT scans are better; however plain film radiography is more widely available. In trauma patients, assessment of the spinal canal is needed immediately for the rapid detection of cervical canal stenosis. The diameter of the AP cervical vertebra of the spinal canal in the average adult male is 17–18 mm at the C3–C5 level, and the size of the spinal canal lower cervical vertebrae ranges from 12–14 mm [4]. Plain films can accurately predict

the cervical spinal canal diameter at the pedicle mid-sagittal top level and can be used as the first step for the evaluation of cervical spinal stenosis [5].

The mid-sagittal diameter of the AP cervical vertebrae of the spinal canal is greater in whites, followed by blacks and, then, Asians. Indonesian people are anthropometrically different from many people in America, Japan, Pakistan, Europe, and Korea [5]. However, studies that have compared mid-sagittal diameters determined by CT and plain film radiography have not been reported. Because of the lack of contrast resolution and the presence of magnification, plain films have been found to be less useful than CT scans (Kock, 1986) [5].

To our knowledge, no studies have compared the accuracy of plain films with CT scans for the measurement of the cervical spinal canal in an Indonesian population. Therefore, the aim of this study was to compare cervical spinal canal morphometric profiles in patients examined at the Cipto Mangunkusumo Hospital by plain film radiography and CT.

2. Methods

This was a cross-sectional study conducted from July 2012 to January 2013 in patients who underwent CT and plain film cervical imaging in the Cipto Mangunkusumo Hospital. A total of 51 patients were initially collected; however, 44 only were included in the correlation analysis. The inclusion criteria were patients who underwent plain film and CT cervical imaging and were 16–60 years old. The exclusion criteria were fractures, tumors, infections, scoliosis, and anomalies.

Of the 51 initial subjects, 26 were males and 25 were females aged 16–60 years. Height and weight were also recorded. There were no deformities. CT scans were performed first (MSCT 2 x 128-slice Siemens Definition Flash; slice thickness, 1.25 mm helical, pitch, +1; window level, bone setting, sagittal reconstruction; slice thickness, 3 mm). If the CT results were normal, it was then continued with AP and lateral x-ray imaging (Philips conventional x-ray; serial number 205351; operated at 73 kV and 16 MAS) of the cervical spine taken in the neutral position at a 100-cm focal-film distance. The measurements were performed as shown in Figure 1. The results were analyzed by using SPSS statistical software to perform independent t-tests and Pearson's correlation analysis.

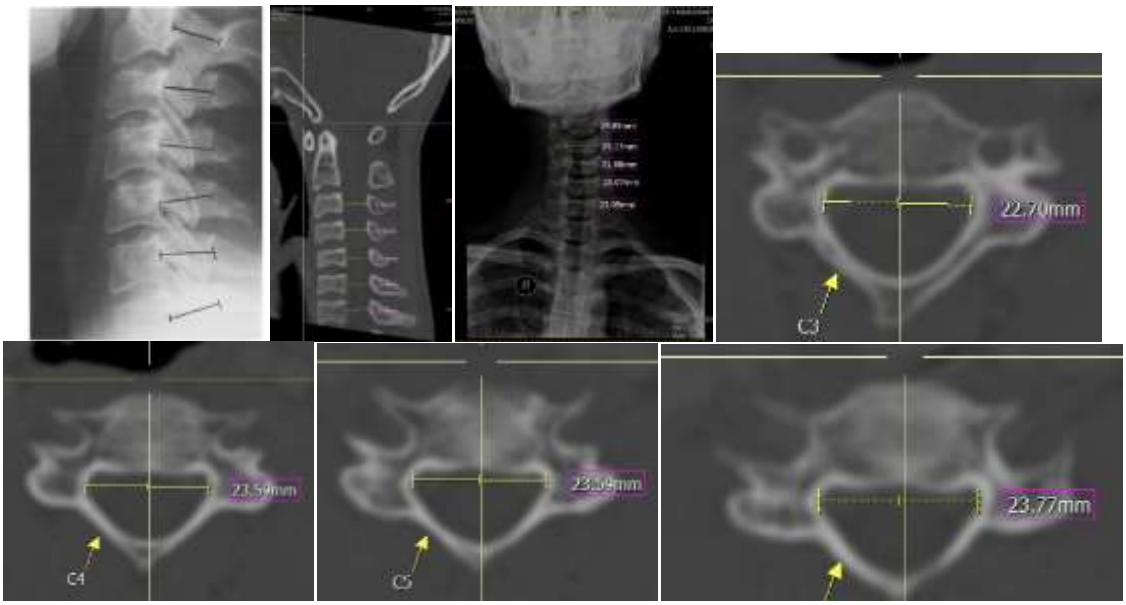

Figure 1. Sagittal diameter: spinal canal sagittal diameter was measured from the center of the posterior vertebral body line to the laminar on the sagittal plane [6–8]. Interpedicular diameter: the width of the transverse distance between the inside surfaces of the medial pedicle on plain AP (Jones and Thomson 1968) [6–8].

3. Results

The 51 subjects (age, 16–60 years; mean age, 37.3 years) included 26 (51.0%) males, and most of the subjects were Javanese (35.3%). Table 1 presents the baseline characteristics of the study subjects.

Table 1. Baseline characteristics of patients

Characteristic	n (%)
Sex	
Male	26 (51.0)
Female	25 (49.0)
Age (year)	
<20	4 (7.8)
20–29	11 (21.6)
30–39	11 (21.6)
40–49	17 (33.3)
50–59	7 (13.7)
60	1 (2.0)
Ethnicity	
Sunda	16 (31.4)
Jawa	18 (35.3)
Betawi	7 (13.7)
Padang	1 (2.0)
Minahasa	3 (5.9)
Makasar	2 (3.9)
NTB	1 (2.0)
Medan	1 (2.0)
Jambi	1 (2.0)
Lampung	1 (2.0)
Body weight (kg)	51.5 (9.9)
Height (cm)	159.1 (6.3)

Figure 2 and 3 show the mean sagittal diameters of the cervical spinal canal measured from plain films and CT scans. The mean cervical spinal canal diameters measured from plain films are given for the largest sagittal diameter at C6 (18 mm) and for the smallest sagittal diameter at C4 (17.0 mm) and for the largest interpedicular diameter at C6 (26.2 mm) and the smallest diameter at C3 (25.2 mm). The mean cervical spinal canal diameters measured from CT scans are given for the largest sagittal diameter at C7 (13.8 mm) and for the smallest sagittal diameter at C4 (12.8 mm) and for the largest interpedicular diameter at C5 (24.4 mm) and for the smallest interpedicular diameter at C3 (22.5 mm).

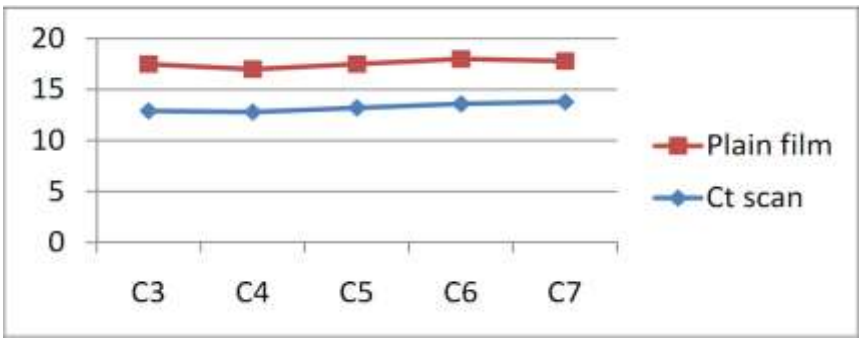

Figure 2. Differences in mean sagittal diameters of the cervical spinal canal between plain films and CT scans

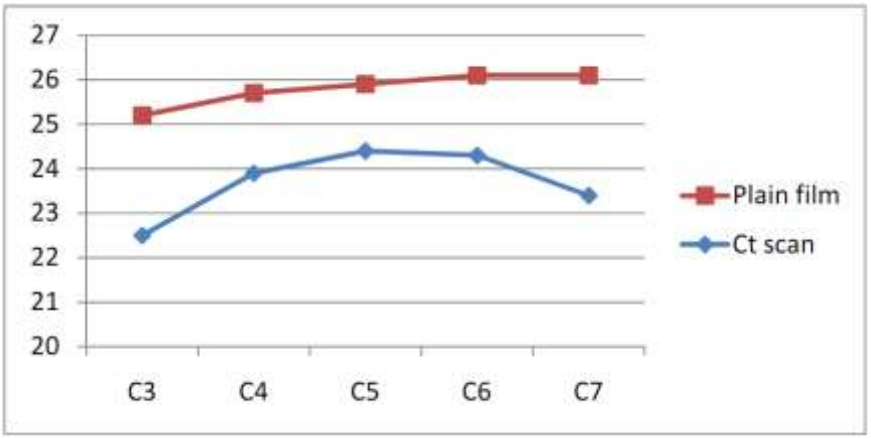

Figure 3. Differences in mean interpedicular diameters between plain films and CT scans

There were significant differences in the mean C3–C7 sagittal and interpedicular diameters measured from plain film between males and females ($p < 0.05$). The largest mean sagittal cervical spinal canal diameter was 18.9 mm at C6 in males and was 17.1 mm at C6 in females; the largest interpedicular diameter was 27 mm at C6 in males and was 25.4 mm at C6 in females

There were no significant differences in the mean sagittal cervical spinal canal and interpedicular C3–C7 diameters obtained from plain film between different age groups ($p > 0.05$).

There were significant differences in the mean sagittal cervical spinal canal and C3–C7 interpedicular C3–C7 diameters obtained from plain film between different body heights ($p < 0.05$); the largest sagittal diameter was 27.1 mm at C6 for body heights of 159–175 cm.

There were significant differences only in the sagittal interpedicular diameters obtained from plain film at C3, C6, and C7 between different weight groups.

4. Discussion

The aim of this study was to compare cervical spine canal morphometric profiles of Indonesian patients examined by plain film radiography and CT. The 51 subjects were divided into groups by sex, age, height, and weight. We found that the mean sagittal diameter of the cervical spinal canal obtained from plain film of patients who went to Cipto Mangunkusumo Hospital was largest at C6 (18 mm) and smallest at C4 (17.0 mm); the largest interpedicular diameter was at C6 (26.2 mm) and the smallest was at C3 (25.2 mm). Our results showed that the mean sagittal cervical spinal diameter on plain films of Indonesian people was greater than the average diameter of the spinal canal at the C6 cervical vertebrae in Japanese people (15.9 $\pm$1.4 mm), in Korean people (17.7 mm in men and 17.0 mm in women), and in Indian people (16.73 mm) but was as great as that in English people (18.8 mm/C6). Murone reported that the cervical canal in Japanese people was significantly smaller than that in Europeans. The mean diameters of the spinal canal interpedicular cervical vertebrae in Indonesians widens at C3–C6 (C3/25.2 mm; C4/25.7 mm; C5/25.9 mm; C6/26.2 mm) and tapers at C7 (26.1) and is smaller than the average size of Koreans (27.1/28.5/28.9/29.1/27.8) and in American people. The interpedicular diameter was almost twice the size of the sagittal diameter of the cervical canal, which means that the interpedicular diameter has more space for the spinal cord and less when the sagittal diameter, for which the sagittal diameter of more value in many measurements (Young, 1967) [9–12].

In Figure 6, the results of measurements with various focus-film distance have different results. Burrows (1963) with a focus distance of 1.83 m c3-c7 (18.5 / 17.7 / 17.7 / 17.5 / 17.3), Nagashima (1973) a distance of 1.5 m c3-c7 (15 , 1/14, 7/14, 3/14, 4/14, 5), Soto and Tsuru (1976) a distance of 1.2 m c3-c7 (16.1 / 15.5 / 15.8 / 16.0 / 15.9) [13].

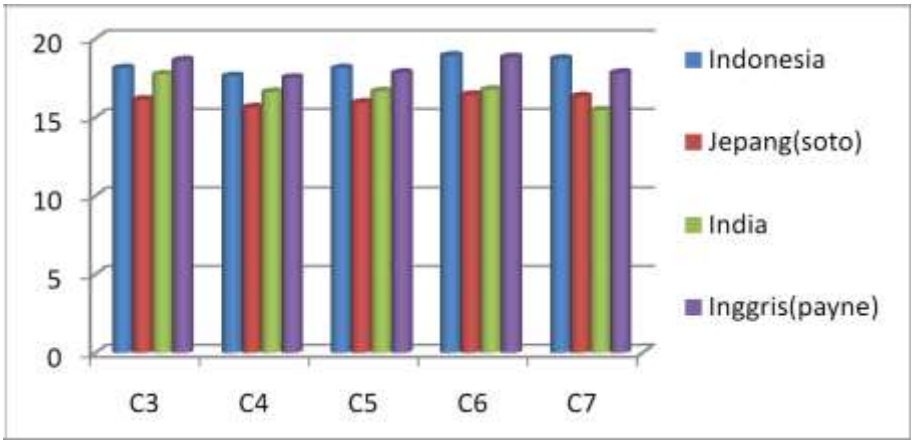

Figure 4. Mean difference in the diameters of the cervical spinal canals in males

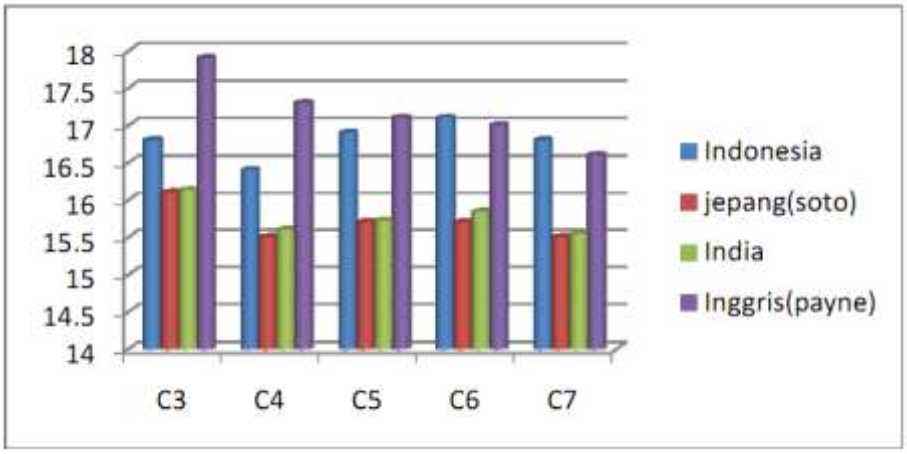

Figure 5. Mean difference in the diameters of the cervical spinal canals in females

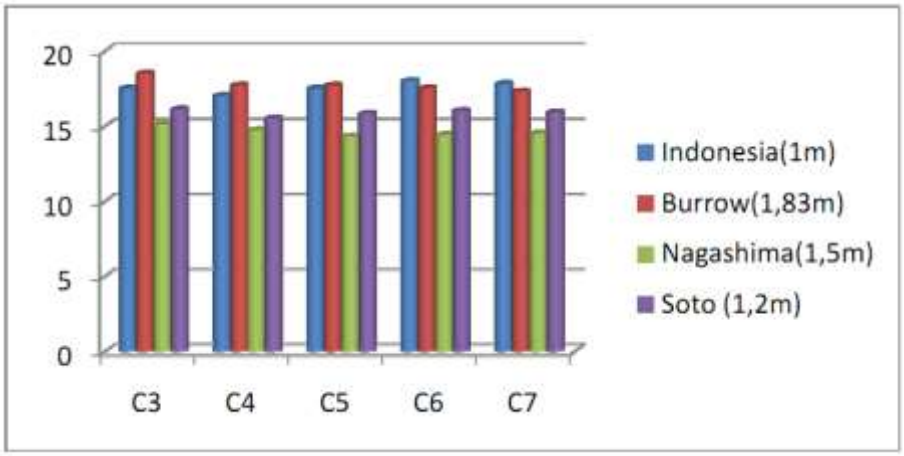

Figure 6. Diameter of the cervical spinal canal by focus-film distance

The factors of sex, weight, and height affected the mean cervical spinal canal diameter, whereas age had no effect. There were significant differences in the mean C3–C7 sagittal and interpedicular diameters measured from plain film between males and females better ($p < 0.05$). The largest mean sagittal cervical spinal canal diameter was 18.9 mm at C6 in males) and was 17.1 mm at C6 in females; the largest interpedicular diameter was 27 mm at C6 in males and was 25.4 mm at C6 in females. The anterior component of the sagittal diameter is determined by the size and position of the articular processes and showed no difference between men and women; however, in women, the posterior component was supported by a smaller lamina of 0.5–1 mm. The incidence of cervical spinal canal stenosis is higher in males, and the cervical spinal canal diameter is greater in men than in women. This was the cause of the canal in women and is more rounded triangular in men [16]. In addition, Hukuda and Kojima evaluated the spinal canal on the basis of gender by comparing the canal to the vertebral body. They found that the canal was significantly larger in women than in men, and this difference helps explain why stenosis is more frequent in men [14]. Size and shape are two factors to be considered in evaluations of the growth of the vertebral body and the cervical spinal canal in relation to genetics and postural and mechanical factors [9].

There were no significant differences in the mean sagittal cervical spinal canal and interpedicular C3–C7 diameters obtained on plain film between different age groups ($p > 0.05$). It does not fit with the reports in the literature that age <40 years was associated with statistically wider morphometric values [13]. Various studies have confirmed that the sagittal diameter of the cervical spinal canal decreased according to age. The process of aging can lead to degenerative changes that can cause compression of the spinal cord [14]. In contrast to the findings of Taitz, there were no differences in the morphometric results between different age groups in this study because of the small number of subjects [15].

In this study, the cervical canal diameter was larger for heights ranging from 159–175 cm (Table 4.8), which is consistent with previous research in Indian subjects that found that the cervical canal diameter was larger with increasing spinal vertebrae distances in the cervical canal [14]. A significant difference in sagittal morphometric values was found only at C6 and C7 between different weight groups on plain film. This finding was consistent with those of previous studies in which increasing weight led to increasing spinal canal size in Indian subjects [14].

In the correlation analysis between the sagittal diameter of the cervical spinal canal and interpedicular cervical vertebrae diameter determined by using plain film and CT scans, only sagittal cervical spinal canal diameter correlated strongly, which means that plain films can be used to detect the presence of cervical canal stenosis without the need for CT. This can be done by applying multiplier factors determined in the correlation analysis.

5. Conclusion

The study results showed that the sagittal diameter of the cervical spinal canal obtained from plain film was correlated with that obtained from CT scans. Instead of CT, plain film radiography can be used for this purpose by applying multipliers of 0.73 at C3, 0.75 at C4–C6, and 0.77 at C7 to the plain film values to obtain the equivalent CT values.

References

[1] Blackley H R, Plank L D and Robertson P A 1999 The reliability of ratio of anatomical measurement in determining the sagittal dimensions of the canal of cervical spine. from Auckland Hospital, New Zeeland. *J. Bone Joint Surg.* **81** 110–2

[2] Tjachyadi D and Onibala M Z 2010 Torg ratios based on cervical lateral film in normal subjects *Univ. Med.* **29** 8–13

[3] Nirvan A B, Pensi C A and Patel J P et al 2005 A study of interpedicular distance of the Lumbar Vertebrae Measured in Plain Anteroposterior Radiograph in Gujaratis. *J Anat Soc India* **54** 2–9

[4] Nadalo L and Moody J C Spinal stenosis imaging. Available From www.emedicine.com. Citated February 17, 2011
[5] Senol U, Cubuk M and Sindel M et al 2011 Anteroposterior diameter of the vertebral canal in cervical region comparison of anatomical computed Tomographic and plain film measurement. *Clin. Anat.* **14** 15–8
[6] Balinger P W 1986 Memil's atlas of radiographic positions and radiologic procedures. volume one, 6th, *The C.V.Mosby Company* 268–308
[7] Greenspan A 2004 Orthopaedic imaging a practical approach, 4th. Lipincot William and Wilkin. Part II. Chapter 11
[8] Fast A and Goldsher D 2007 Navigating the adults spine. Bridging clinical practise and neuroradiology, USA. (New York: Demos Medical Publishing) pp.3–6
[9] Bajammal S Cervical spondylosis Orthopaedic PGY2. Neurosurgery Half Day, Dec 20: 2002
[10] Lee H W, Kim N H and Kim H J 1994 Midsagittal canal diameter and vertebral body/canal ratio the cervical spine in Koreans *Yonsei Med. J.* **4** 446–51
[11] Oon L 1974 The sagital diameter of the cervical spinal canal *Singapore Med. J.* **15**
[12] Tossel G Dimensions of the cervical spinal canal in the south africans negroid population. In the school medicine, faculty of health sciences university of pretoria (South Africa; 2005-2007)
[13] Bajammal S Cervical spondylosis. Orthopaedic PGY2. Neurosurgery Half Day,Dec 20: 2002
[14] Gupta S K, Roy R C and Srivastava A 1982 Sagittal diameter of the cervical canal in normal indian adults. Department of radiodiagnosis. Institutes of medical Science, banaras Hindu University , Varanasi, India. *Clin. Radial.* **33** 681–5
[15] Goto S I, Umehara J and Kokubun S et al 2010 Comparison of cervical spinal canal diameter between younger and elder generation of Japanese *J. Orthopaedic Sci.* **15** 97–103
[16] Perdigao J and Swift E J 2006 Fundamental Concepts of Enamel and Dentin Adhesion *Sturdevants's Art and Science of Operative Dentistry* eds TM Roberson, HO Heymann, EJ Swift, 5th edition (St. Louis: Mosby, Elsevier) 248–64