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Quantitative analysis of the cervical spinal canal by computed tomography

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Summary. Computed tomography measurements of the AP diameter, width, and cross-sectional area of the bony cervical canal were derived from cervical spine examinations of fifty-two normal adults. These quantitative parameters were then used to evaluate 80 patients with various cervical abnormalities to determine the clinical usefulness of the measurements. With the exception of spinal stenosis, quantitative cervical canal analysis was found to be of limited usefulness since normal measurements frequently occurred in the presence of significant cervical pathology.

Key words: Cervical spine - Quantitative - CT spine

The merits of CT spinal evaluation have been well described [1-20]. In particular, CT of the lumbosacral spine has received much attention in the literature [1-9]. Nomograms have been established for normal lumbar spine measurements [6, 7] and are used when evaluating patients with suspected lumbar spine disease. In contrast, the cervical spine has received less attention. While plain radiographs and standard myelography provide important information regarding canal abnormalities, CT is often superior in the overall evaluation of the spine [9-16]. Despite some limitations [4, 13, 17] plain CT has been advocated in the initial investigation of patients with suspected spine abnormalities [8, 17, 18]. Although the merits of CT assisted metrizamide spine exams continue to be demonstrated [8, 11, 13, 15, 17-20], the examination is invasive and not without side effects. Therefore plain CT examination of the spine may continue to be used as an initial screening examination of some abnormalities. Quantitative cervical spine measurements can be readily obtained from plain CT examinations. The following study was undertaken to derive normal cervical spine measurements and determine their clinical usefulness in the evaluation of patients with pathological states.

Materials and methods

Fifty-two consecutive volunteers with no neurologic history attributable to the cervical spine formed the study group. They were examined prior to standard

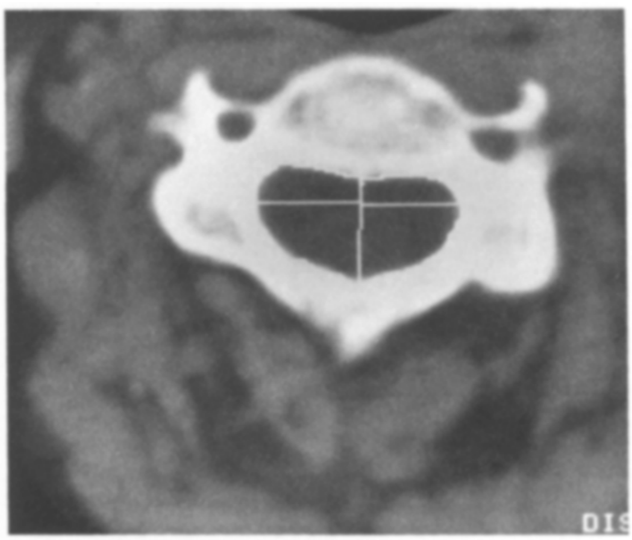

Fig. 1. The maximum AP diameter, width, and cross-sectional area were measured at a wide window setting of 1000 and level of (+) 200 HU

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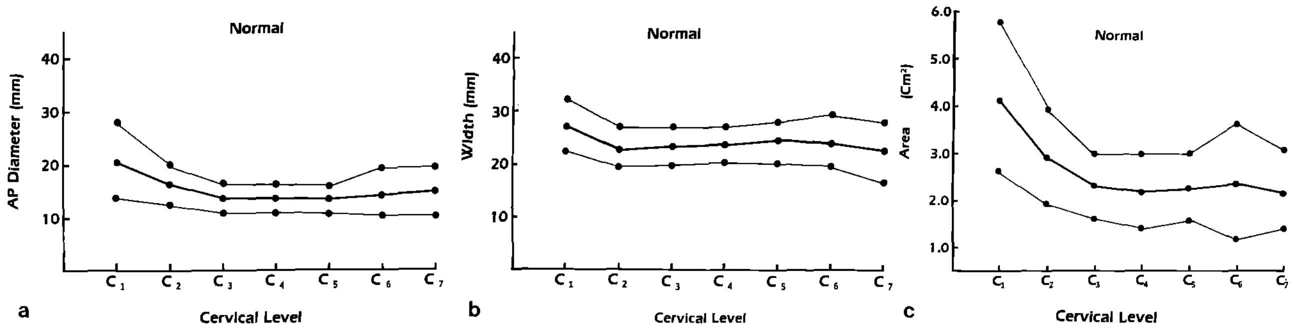

Fig. 2 a–c. Nomograms of the cervical AP diameter **a**, width **b**, and cross-sectional area **c** are shown. The central heavy black line represents the mean value, and the lines above and below represent the normal range (±2 standard deviations)

Table 1. Measurements (±2 S.D.)

Vertebral level	A/P Diameter (CM)	Width (CM)	Area (CM^2)
C1	2.14 (0.64)	2.82 (0.52)	4.24 (1.52)
Range	(1.50-2.78)	(2.30-3.34)	(2.72-5.76)
C2	1.69 (0.34)	2.37 (0.40)	2.89 (0.94)
Range	(1.35-2.03)	(1.97-2.75)	(1.95-3.83)
C3	1.40 (0.30)	2.37 (0.40)	2.30 (0.74)
Range	(1.1 -1.7)	(1.97-2.77)	(1.56-3.04)
C4	1.40 (0.30)	2.43 (0.40)	2.25 (0.82)
Range	(1.1 -1.7)	(2.03-2.83)	(1.43-3.07)
C5	1.40 (0.26)	2.45 (0.40)	2.31 (0.70)
Range	(1.14-1.66)	(2.05-2.85)	(1.61-3.01)
C6	1.45 (0.42)	2.42 (0.50)	2.44 (1.21)
Range	(1.03-1.87)	(1.92-2.92)	(1.23-3.65)
C7	1.5 (0.44)	2.29 (0.52)	2.25 (0.82)
Range	(1.05-1.94)	(1.77-2.81)	(1.43-3.07)

Table 2

Pathologic conditions		Abnormal measurements	
Herniated discs	13	1	(8%)
Spondylosis	24	19	(79%)
Fractures	22	3	(14%)
Syringomyelia	9	2	(22%)
Neoplasms	6	2	(33%)
AVM	1	1	(100%)
Spinal stenosis	5	5	(100%)
Total	80	33	(41%)

head CT or neck CT examinations for suspected parotid, thyroid, or parathyroid gland abnormalities. Equal numbers of males and females with an age range of 15–74 years, (average 42) were examined. Patients with minor degenerative changes were included, provided no degenerative spur encroached upon the cervical canal. All scans were performed on a GE 8800 CT scanner, using 120 kVp, 9.6 second scans. All measurements were made directly from the CT video image using the standard internal measurement device of the CT scanner.

A single 1 cm thickness scan was made through the mid portion of each vertebral body. Using methods similar to those previously described for plain film measurements of the cervical spine [22], CT slices were oriented perpendicular to the posterior surface of the vertebral body through the closest portion of the cortical line of the neural arch (the midline of the spinal canal posteriorly). The radiation dose to the neck was measured at approximately 2.5 rads per slice using this technique [26].

The cervical spinal canal was measured in the greatest AP diameter, width, and cross sectional area (Fig. 1) by two observers. Both magnified and non magnified views and measurements were obtained. Magnified, non-magnified and interobserver measurements always varied by less than 5%. The appropriate level and window setting for these measurements as well as the accuracy of the internal measuring device of the CT scanner were determined using the Alderson Research Phantom[1]. The phantom has a bone density block within a plastic matrix. At a wide window CT setting of 1000 HU, and level of (+) 200 HU, CT measurements obtained by 2 observers were within 4% of the actual size of the bone density block within the phantom. Additional measurements were made at window levels of 0 HU, (+) 100 HU, and (+) 300 HU, and all were found to vary from the actual object size by less than 5%.

The cervical canal AP diameter, width, and cross sectional area, ±2 standard deviations at each cervical level, were calculated. Cervical canal measurements were considered abnormal if outside this range. The measurements of the cervical canals of 80 patients with various cervical abnormalities were then compared to the normal values.

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Results

The normal measurements of the cervical spine are shown in graphs (Fig. 2), and summarized in Table 1. The greatest AP diameter, width, and area as well as the largest standard deviation of the cervical canal occurred at CI. The smallest AP diameter of the canal occurred at C_3, C_4 and C_5. The cross-sectional area was smallest at the C_4 and C_7 level.

Eighty patients with cervical abnormalities were measured: thirteen with cervical disc abnormalities, 24 with symptomatic spondylosis, 22 with cervical spine trauma, nine with cervical syringomyelia, seven with cervical cord neoplasm, and five with congenital diffuse spinal stenosis.

Thirteen patients had cervical disc herniation without evidence of associated significant cervical spondylosis. Disc herniation was documented with metrizamide myelography, CT metrizamide myelography, and/or surgery. Eleven of this group had a radiculopathy, one a radiculopathy and myelopathy, and one a myelopathy. Only one (8%) with associated congenital spinal stenosis and myelopathy had abnormal canal measurements.

Of nine patients with syringomyelia or hydromyelia documented with CT and myelography, only one had cervical canal measurements larger than normal. One of the nine had an unexplained small canal associated with spinal cord atrophy.

Twenty-four patients had cervical spondylosis. Their neurologic symptoms ranged from intense radicular pain to a severe myelopathy with progressive quadraparesis. Five of these 24 patients had normal canal measurements. In the 19 patients with abnormal canal measurements, the AP diameter was the parameter most frequently affected (31 levels). The cross-sectional area was abnormal at 18 levels, both the AP diameter and cross-sectional area at 16 levels, and the width, AP diameter, and area abnormal at six levels. The width was small at only seven levels. Patients averaged two affected cervical levels with a range of one to four levels, and C_4, C_5, C_6 were the levels most commonly involved. Four patients had AP measurements less than 10 mm and all four had progressive quadraparesis.

Twenty-two patients had cervical spine fractures. Twelve had focal neurologic findings which eventually resolved and all had normal cervical spine measurements. Ten patients had persistent focal neurologic deficits and seven of ten had normal cervical canal measurements despite serious fractures. CT assisted metrizamide myelography demonstrated contusion or compression secondary to hematomas in this group. The remaining three had canal measurements that were abnormal, with the most common abnormality being a diminished AP diameter secondary to fracture fragments.

Six patients with cervical cord neoplasms and one patient with a cervical cord arteriovenous malformation (AVM) were grouped together. Three of the seven had abnormal measurements. The patient with the AVM had an enlarged canal with a large cross-sectional area at 5/7 cervical levels. The AP diameter was large at two levels. Arteriography demonstrated diffuse involvement of the cervical cord with the AVM. The second patient had a cervical meningioma with an enlarged cross-sectional area from C_1 to C_4. The third patient had neurofibromatosis associated with an extramedullary neurofibroma and an enlarged canal from C_3 to C_7.

Five patients with a progressive myelopathy were found to have a congenital, diffusely small bony cervical canal. Metrizamide myelography showed diffuse canal narrowing. The abnormal cervical spines are summarized in Table 2.

Discussion

CT provides a simple, fast, and accurate method of measuring the cervical spinal canal. Accurate measurements can be obtained from non-magnified images shortening the time required to perform the exam. Although previous examiners have cautioned that visually appealing images may not provide accurate anatomical quantitative data [21], we have shown accurate spinal canal measurements can be made over a wide range of window levels.

The CT canal measurements of the AP diameter differed from commonly used plain film measurements [22, 23]. Overall the AP diameter was smaller with a smaller range of normal values. This most likely was due to lack of magnification with CT. The plain film and CT graph of the AP contour appeared similar with the exception of slight expansion of C_6 and C_7 on CT. At these levels a larger standard deviation occurred than at the more uniform C_3, C_4, and C_5 levels. By our measurements 10 millimeters must be considered the lower limits of normal at C_6, C_7 although no normal patient had a canal less than 11 mm in the AP diameter. Despite the use of gantry angulation a true perpendicular relationship between the plane of the CT section and central axis of the cervical spinal canal was more difficult to obtain here, leading to a larger standard deviation.

We compared plain film interpedicular measurements of C_{3-7} [24] and found them to be similar to the CT canal width measurements. Again the CT measurements were smaller, however, the graph contours of the CT and plain film measurements appeared similar.

The CT cross-sectional area, AP diameter, and width of the cervical spinal canal have not been previously established, although others have evaluated the size of the cervical cord with myelography [25] and CT-assisted myelography [26]. The cord was widest in the mid-cervical area. Its AP diameter was greatest at C_1 with an AP bulge at C_7 slightly greater than the mid cervical portion of the cord. With the exception of the C_1 width, which was the greatest, the graph appeared similar to those of cord measurements. Our 10 mm lower limit of normal for the AP diameter of the spinal canal is in agreement with the 9.3 mm upper limits of normal for sagittal cord size [25].

Most abnormal spinal measurements occurred in patients with neurologic symptoms due to bony compression of the cervical spinal cord. This occurred most frequently with spondylosis and congenital spinal stenosis. The parameter most commonly affected in spondylosis was the AP diameter, due to large osteophytes arising from the posterior aspect of the vertebral body. All four patients with spondylosis and AP diameters less than 10 mm had progressive quadraplegia.

The cross-sectional area was the parameter most frequently abnormal in patients with congenital diffuse spinal stenosis and in patients with generalized expansive processes such as neoplasms and syringomyelia. The width was the parameter least commonly affected and of the least clinical value in such patients.

Nineteen of twenty four patients (79%) with cervical spondylosis had small canal measurements. Despite the fact that the majority of patients with spondylosis had abnormal measurements, the use of quantitative data alone would have underestimated the extent of disease in the cervical spine. Quantitative analysis of canal measurements detected abnormalities at only thirty-six cervical spine levels in the nineteen patients. Myelography and CT-assisted myelography demonstrated osteophytes producing cord or nerve root compression capable of accounting for the patient's symptoms at 73 cervical levels. Thus quantitative parameters alone should not be used to evaluate patients with spondylosis.

Five patients with diffusely small canals and a progressive myelopathy were studied. Plain cervical spine films suggested spinal stenosis and plain CT with quantitative data documented diffuse narrowing of the cervical bony canal. Metrizamide myelography was useful in excluding other pathology. Three of the patients underwent cord decompression in the already compromised small canal, with subsequent improvement in their neurologic deficits.

Large canals occurred infrequently (4/78 or 5%), but when present were due to neoplasm or syringomyelia. Arteriography, myelography, or CT assisted myelography was necessary to establish a diagnosis in this group. All had neurologic symptoms of such severity that regardless of the canal measurements additional studies were indicated.

In the remainder of abnormal patients, quantitative data was of little clinical usefulness. Only 1/11 patients with a herniated cervical disc, two of nine cases of syringomyelia, three of seven cord neoplasms, and 3/22 cervical spine fractures had abnormal parameters. Severe neurologic deficits were frequently present despite the normal plain CT appearance and size of the cervical bony canal. Myelography or CT assisted myelography was usually needed to establish a diagnosis in these patients.

In summary, plain CT is an accurate non-invasive method to quantitatively assess the bony cervical canal. Our measurements for canal AP diameter, width, and cross sectional area compare favorably with previous quantitative studies of the cervical canal and spinal cord size. However, quantitative parameters were found to be of limited clinical usefulness when evaluating patients with cervical pathology. Using quantitative data alone the extent of spondylosis would have been grossly underestimated. Most patients with cord neoplasms, syringomyelia, trauma, and cervical discs had normal canal measurements.

The one group in whom quantitative cervical canal assessment best provided information regarding the presence and extent of disease was spinal stenosis. Once this condition is suspected from plain cervical spine films, the spinal canal can be best evaluated with CT. Abnormal quantitative data can provide additional diagnostic support that spinal stenosis is present.

References

1. Hammerschlag SB, Wolpert SM, Carter BL (1976) Computed tomography of the spinal canal. Radiology 121: 361-367
2. Williams AL, Haughton VM, Daniels DL, Thornton RS (1982) CT recognition of lateral lumbar disk herniation. AJR 139: 345-347
3. Dorward RH, DeGroot J, Sauerland EK, Helms CA, Vogler JB (1982) Computed tomography of the lumbosacral spine: Normal anatomy, anatomic variants and pathologic anatomy. Radiographics 4: 459-498
4. Cacayorin ED, Kieffer SA (1982) Applications and limitations of computed tomography of the spine. Radio Clin North Am 20: 185-206
5. Sheldon JJ, Sersland T, Leborgne J (1977) Computed tomography of the lower lumbar vertebral column. Radiology 124: 113-116

6. Lee BCP, Kazam E, Newman AD (1978) Computed tomography of the spine and spinal cord. Radiology 129: 95-102
7. Ullrich CG, Binet EF, Sanecki MG, Kieffer SA (1980) Quantitative assessment of the lumbar spinal canal by computed tomography. Radiology 134: 137-143
8. Anand AK, Lee BCP (1982) Plain and Metrizamide CT of lumbar disk disease: comparison with myelography. AJNR 3: 567-571
9. Haughton VM, Eldervik OP, Magnaes B, Amundsen P (1982) A prospective comparison of computed tomography and myelography in the diagnosis of herniated lumbar disks. Radiology 142: 103-110
10. Harbin WP (1982) Metastatic disease and the nonspecific bone scan: value of spinal computed tomography. Radiology 145: 105-107
11. Post MJD, Green BA, Quencer RM, Stokes NA, Callahan RA, Eismont FJ (1982) The value of computed tomography in spinal trauma. Spine 7 (5): 417-431
12. Larde D, Mathieu D, Frija J, Gaston A, Vasile N (1982) Vertebral osteomyelitis: disk hypodensity on CT. AJR 139: 963-967
13. Roub LW, Drayer BP (1979) Spinal computed tomography: limitations and appliations. AJR 133: 267-273
14. Nakagawa H, Juang VP, Malis LI, Wolf BS (1977) Computed tomography of intraspinal and paraspinal neoplasms. J Comput Assist Tomogr 1: 377-390
15. Resjo MI, Harwood-Nash DC, Fitz CR, Chuang S (1979) CT metrizamide myelography for intra-spinal and paraspinal neoplasms in infants and children. AJR 132: 367-372
16. Carrera GF, Foley WD, Kozin F, Ryan L, Lawson TL (1981) CT of sacroiliitis. AJR 136: 41-46
17. Dublin AB, McGahan JP, Reid MH (1983) The value of computed tomographic Metrizamide myelography in the neuroradiological evaluation of the spine. Radiology 146: 79-86
18. Scotti G, Scialfa G, Pieralli S, Boccardi E, Valsecchi F, Tonon C (1983) Myelopathy and radiculopathy due to cervical spondylosis: Myelographic-CT correlations. AJNR 4: 601-603
19. Nakagawa H, Okumura T, Sugiyama T, Iwata K (1983) Discrepancy between Metrizamide CT and Myelography in diagnosis of cervical disk protrusions. AJNR 4: 604-606
20. Barrow DL, Wood JH, Hoffman JC (1983) Clinical indications for computer assisted myelography. Neuro Surg 12: 47-57
21. Koehler PR, Anderson RE, Baxter B (1979) The effect of computed tomography viewer controls on anatomical measurements. Radiology 130: 189-194
22. Wolf BS, Khilnani M, Malis L (1956) The sagittal diameter of the bony cervical spinal canal and its significance in cervical spondylosis. J Mt Siani Hospital 23: 283-292
23. Nordquist L (1964) The sagittal diameter of the spinal cord and subarachnoid space in different age groups. Acta Radiologica [Suppl] 227: 1-96
24. Hinck VC, Clark W, Hopkins C (1966) Normal interpedicular distances: minimum and maximum in children and adults. AJR 97: 141
25. Lamont AC, Zachary J, Sheldon PWE (1981) Cervical cord size in Metrizamide myelography. Clinical Radiology 32: 409-412
26. Thissen HOM, Keyser A, Horstink MWM, Meijer E (1979) Morphology of the cervical spinal cord on computed myelography. Neuroradiology 18: 57-62
27. Frey GB, Wise JP, Ross PR (1980) Evaluation of CT units. Optical Engineering 19: 392-396

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