**How to Cite:**
Jee, K., Yadav, Y., & Kaul, N. V. (2022). Morphometric analysis of cervical canal stenosis using computerized tomography (CT) scan in a North Indian Community. *International Journal of Health Sciences*, *6*(S9), 1542–1553. https://doi.org/10.53730/ijhs.v6nS9.12613

# Morphometric analysis of cervical canal stenosis using computerized tomography (CT) scan in a North Indian Community

**Kanhaiya Jee**
Research Scholar, Department of Anatomy, Santosh Medical College, Ghaziabad-201009, NCR, Delhi, Uttar Pradesh
Mobile number-9628004440
Corresponding author email: kanhaiyaj51@gmail.com

**Yogesh Yadav**
Professor, Dept. of Anatomy, Santosh Medical College, Ghaziabad, UP

**Nisha V Kaul**
Professor and Head, Dept. of Anatomy, Santosh Medical College, Ghaziabad, UP

***Abstract*---**Introduction: Cervical spinal stenosis is a frequent condition that causes a lot of pain and disability. To avoid long-term disability as a result of irreversible spinal cord injury, quick diagnosis and treatment are required. Cervical vertebrae have smaller bodies than other vertebrae, and their purpose is to support the head, protect the spinal cord, and permit head movement. Material and Methods: A case control study has been undertaken at a tertiary care setting of Uttar Pradesh for a period of 1 year from June 2020 to May 2021. Patients with either cervical spine stenosis or facet joint arthrosis or both aged between 20 to 80 years of either gender who attended Out-patient departments of the hospitals were involved. Results: A sum of 83 individuals were made part of the Case group and 50 patients were included as the Controls. Around 50% of the case population were females (n=42) and 56% of the controls were males (n=28). The Mean±SD Torg ratio of C3 cervical vertebra among the case group was 0.78±0.05, where as it was 0.84±0.06 in the control group. Mean±SD Torg ratio of C4 cervical vertebra among the case group was 0.76±0.05, whereas it was 0.83±0.08 in the control group. Discussion: The Mean Torg ratio of cervical vertebrae C3-C4 declines gradually from C3 (0.780.05) to C7 (0.760.05) in our study. The Mean Torg ratio remains constant at the C4-C7 level. Radicular pain is caused by direct compression of major nerve roots, which can occur either within the spinal canal, at their exit zones, or outside the vertebral column. Conclusion: The conventional lateral plain x-ray technique can be replaced with a Computed Tomography scan, which could offer


*Manuscript submitted: 9 May 2022, Manuscript revised: 18 July 2022, Accepted for publication: 27 August 2022*

appropriate measures of cervical canal that can be used as a tool in determining cervical canal stenosis.

***Keywords*---**Cervical vertebrae, Computed Tomography, Morphometry, Pain, Spinal canal.

## Introduction

Cervical spinal stenosis is a frequent condition that causes a lot of pain and disability. To avoid long-term disability as a result of irreversible spinal cord injury, quick diagnosis and treatment are required. Cervical vertebrae have smaller bodies than other vertebrae, and their purpose is to support the head, protect the spinal cord, and permit head movement (in flexion, extension, and rotation). The cervical vertebrae are both normal and uncommon, yet they share many characteristics. The first and second cervical vertebrae are unusual in that they have different characteristics. The skeleton of the neck is formed by the cervical spine, which transmits the weight of the upper body to the pelvis and is thus exposed to internal tension.[1,2]

In numerous studies, a considerable number of persons have neck pain at some point in their lives, and their spinal canal morphometry ranges are affected. Genetic, hormonal, and other variables may cause variances in results. The cervical chord is affected by spinal cord compression in 10% of instances, with a frequency of 24.4 percent. Infections, tumors, traumaand the deteriorative changessuch as osteophytes, herniation of intervertebral disc, and longitudinal ligaments ossificationposteriorly can all cause the cervical canal to narrow. Pain is the most prevalent presenting symptom, followed by numbness, tingling, weakness, gait instability, bowel and bladder problems, spasticity and paresthesia, and, in rare cases, irreversible paraplegia.These variables may cause increasing cord compression, culminating in spinal cord ischemia and histopathologic alterations in the cervical spinal cord.[3,4]

Zygapophyseal joints, other name for facet of jointsaffected by “osteoarthritis (OA) of the spine”. The only real synovial joints connecting neighboring spinal levels in humans are these paired diarthrodial joints in the posterior part of the vertebral column. Facet joint osteoarthritis (FJ OA) is closely linked to degenerative disc disease, a separate but functionally related syndrome that affects components in the anterior spinal column. Both FJ OA and degenerative disc disease are known to be common causes of back and neck pain, which has a huge impact on industrialised countries' health-care systems and economics.[5,6]

At some point in their lives, the majority of adults will have neck pain that radiates to their upper limbs. Cervical spinal canal stenosis is a common cause of this issue. The cervical spinal canal, which houses the spinal cord and its covering meninges, meningeal blood vessels, and spinal nerve roots, narrows in this illness. This stenosis has long been thought to be a risk factor for cervical spondylotic myelopathy, which is caused by cervical spondylosis, as well as cervical neuropraxia, which is caused by trauma, degeneration, and

inflammation. According to a study, 82 percent of persons aged 54 and up had radiologic evidence of cervical spine degeneration.[7]

All of the spinal compression force is sustained by the vertebral bodies and intervertebral discs, which rises in magnitude from the axis vertebra to the lumbosacral joint. Radiologically detected narrowing of the Sagittal diameter of the cervical canal in the adult spine as a causal factor. The most essential structures in influencing the biomechanical qualities of the cervical spinal column are the zygopophyseal or facet joints. The spinal canal is a hollow tunnel formed by the foramen of the vertebrae that the spinal cord passes through. The narrowing of the spinal canal, known as stenosis, has been linked to neurological damage. Stenosis can be inherited, but it is more usually acquired.[8,9]

Congenital stenosis, also known as spinal stenosis of developmental type, is characterised by a skeletal hypoplasia in which the dimensions of the cervical canal are diminished. In contrast, acquired spinal stenosis arises as a result of degenerative changes, which most typically begin at the level of the disc space. These two diseases are frequently encountered together, and they operate together to compress the spinal cord and cause clinical symptoms. The goal of this study was to use a CT scan to determine the prevalence of cervical canal stenosis and facet joint arthrosis in patients with neck discomfort, as well as the relationship between age, sex, and cervical spinal levels (C3-C7).[10]

There has been no report or study analysing cervical canal stenosis and associated facet joint arthrosis in males and females as the leading cause of age-related neck discomfort until recently, to our knowledge. As a result, we postulated that facet joint arthrosis and cervical canal stenosis are two of the most common causes of age-related neck pain in both men and women. The efficiency of CT scan as a diagnostic tool for cervical discomfort owing to cervical spine stenosis and facet joint arthrosis was also evaluated in this study, which will help clinicians and radiologists communicate better. The findings of this study might be expanded into an independent study with a bigger sample size to investigate the relationship between facet joint arthrosis and cervical canal stenosis and age-related neck pain, which could pave the way for future research in both sexes.

**Material and Methods**

A case control study has been undertaken at a tertiary care setting of Uttar Pradesh for a period of 1 year from June 2020 to May 2021. Patients with either cervical spine stenosis or facet joint arthrosis or both aged between 20 to 80 years of either gender who attended Out-patient departments of the hospitals were involved. After taking necessary ethical permissions from the institution, with reference number SU/2020/2231[7], total of 83subjects were made part of this study by random selection method. Patients aged 20 years and above, healthy according to the Questionnaire, Paresthesia related to movement of neck, sensibility loss corresponding to a particular dermatome, weakness of muscles, muscular atrophy and rigidity of neck were included as cases in study. Individuals below 20 years age**,** Previous trauma (Head or Spine), Surgery of Head or Spine**,** Psychiatric disorder**,** Drug abuse**,** Tumor of head and neck, Pregnancy,

Neoplasia**,** anomalies by birth related to the spinal cord were excluded from this study. Retrospective case data of 83 normal healthy subjects from Radiology department at a tertiary care setting in different age group whose CT scan has been done for conditions unrelated to cervical spine were considered as control group. Any retrospective case data of history of pain in the neck, paresthesia related with neck movement, sensibility loss corresponding to a particular dermatome, weakness of muscles, Muscular atrophy, Rigidity of neck were excluded from control group. (Figure 1 & 2)

After taking informed consent from the patients, demographic data was recorded and questionnaire was filled for final selection of subject as per inclusion and exclusion criteria. Anthropometric data was recorded in the patient proforma.CT scan examination was performed for every patient and the images were interpreted by at least one senior Radiologist who is experience in reporting the CT scan.The cervical vertebra in consideration was from "$C_3$ to $C_7$. $C_1$ and $C_2$"and are not involve because of thedifferent shape in comparison to another cervical vertebra

Figure 1 shows measurement AP diameter of cervical canal

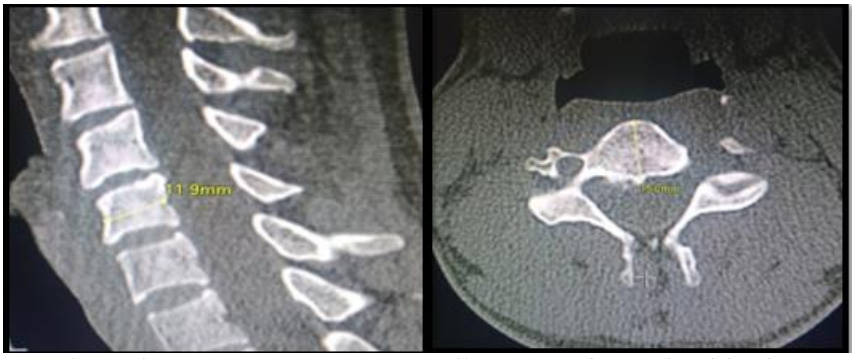

Fig 2 shows measurement AP diameter of vertebral body

**Statistical Analysis**

SPSS (v.24) software was used to analyze the data and to compare data related to the non-degenerative facet joints and arthritic changes across the different ages, Chi-square tests were used. P value of <0.05 has beenregarded as statistically significant.

**Results**

Table 1: Baseline demographics of study population

| Category | Controls | Study Population | P-value |
|---|---|---|---|
| N | 50 | 83 | |
| Gender, n (%) | | | |
| Male | 28 (56.0) | 41 (49.4) | **0.046** |
| Female | 22 (44.0) | 42 (50.6) | |
| Age in years | | | |
| Mean ±SD | 55.21±7.12 | 57.01±7.20 | **0.016** |
| Range | 38-72 | 40-74 | |
| Categories of age, n (%) | | | |
| 40-50 | 6 (12.0) | 14 (16.8) | 0.763 |
| 51-60 | 26 (52.0) | 36 (43.3) | |
| 61-70 | 16 (32.0) | 30 (36.1) | |
| >70 | 2 (4.0) | 3 (3.6) | |
| Height in cms | | | |
| Mean ±SD | 164.21±8.12 | 166.18±8.37 | **0.018** |
| Range | 154.1-176.6 | 155.8-177.5 | |
| Weight in kg | | | |
| Mean ±SD | 68.22±9.78 | 67.47±9.71 | 0.667 |
| Range | 48-88 | 49-87 | |
| Body mass index (BMI), kg/m2 | | | |
| Mean ±SD | 24.40±3.81 | 24.20±3.72 | 0.766 |
| Range | 16-33 | 16-33 | |
| Categories of weight, n (%) | | | |
| Healthy weight | 24 (48.0) | 43 (51.8) | 0.821 |
| Underweight | 2 (4.0) | 5 (6) | |
| Overweight | 20 (40.0) | 31 (37.3) | |
| Obese | 4 (8.0) | 4 (4.8) | |

Table 2: Mean Torg ratio of cervical vertebrae C3-C7 in the study population

| Cervical vertebrae | | Controls | Study population | P-Value |
|---|---|---|---|---|
| N | | 50 | 83 | |
| C3 | Mean±SD | 0.84±0.06 | 0.78±0.05 | 0.0001 |
| | Min | 0.76 | 0.66 | |
| | Max | 1.00 | 0.91 | |

| | | | | |
|---|---|---|---|---|
| C4 | Mean±SD | 0.83±0.08 | 0.76±0.05 | 0.0001 |
| | Min | 0.68 | 0.64 | |
| | Max | 1.01 | 0.88 | |
| C5 | Mean±SD | 0.82±0.06 | 0.75±0.05 | 0.0001 |
| | Min | 0.74 | 0.64 | |
| | Max | 0.98 | 0.87 | |
| C6 | Mean±SD | 0.82±0.06 | 0.76±0.05 | 0.0001 |
| | Min | 0.69 | 0.65 | |
| | Max | 0.97 | 0.88 | |
| C7 | Mean±SD | 0.82±0.06 | 0.76±0.05 | 0.0001 |
| | Min | 0.72 | 0.64 | |
| | Max | 0.96 | 0.88 | |

Table 3: Frequency of neurologic symptoms in study population

| Neurologic Symptoms | Frequency (n) | Percentage (%) |
|---|---|---|
| Pain | 82 | 98.8 |
| Numbness | 44 | 53.0 |
| Tingling | 21 | 25.3 |
| Weakness | 6 | 7.2 |
| Gait Instability | 5 | 6.0 |

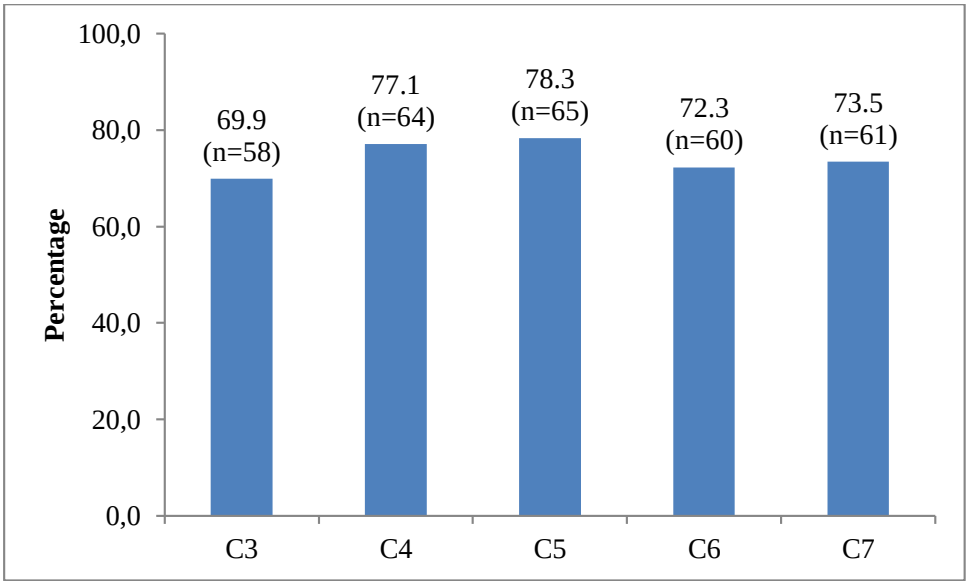


Figure 3: Clinically confirmed cervical stenosis

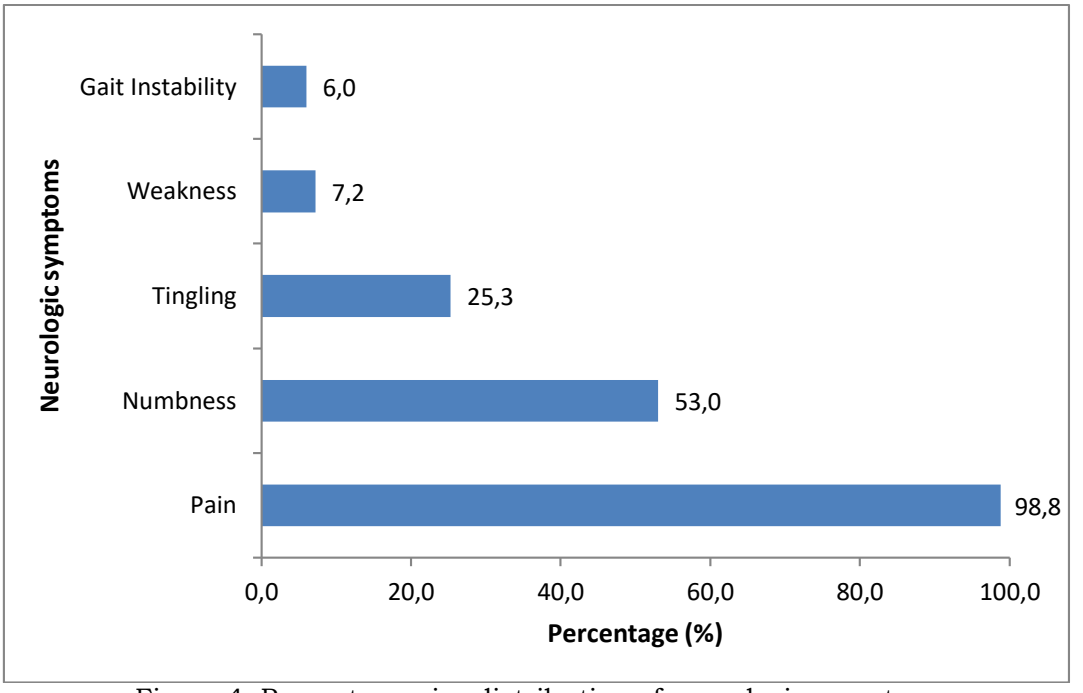


Figure 4: Percentage wise distribution of neurologic symptoms

A sum of 83 individuals were made part of the Case group and 50 patients were included as the Controls. Around 50% of the case population were females (n=42) and 56% of the controls were males (n=28). The observed Mean+SD age (in kgs) observed among the cases was 57.01±7.20, whereas it was 55.21±7.12 among the control group. Majority of the case group belonged to 51-60 age group (43.3%) and majority of the control group belonged 41-50 age group (52%). The Mean +SD height (in cm) in the case group was 166.18±8.37 and it was 164.21±8.12 among the control group. The Mean +SD BMI (in kg/$m^2$) was 24.20±3.72 among the case group and it was 24.40±3.81among the controls. Majority of patients among the case group (51.8%) and the control group (48%) were healthy weighted. Only the variables of gender, age and height were statistically significant with a p value of <0.05. (Table 1).

Mean Torg ratio of cervical vertebrae C3-C7 in the study population was detailed in Table 2. The Mean±SDTorg ratio of C3 cervical vertebra among the case group was 0.78±0.05, whereasit was 0.84±0.06 in the control group. Mean±SDTorg ratio of C4 cervical vertebra among the case group was 0.76±0.05, whereas it was 0.83±0.08 in the control group. The Mean±SDTorg ratio of C5 cervical vertebra among the case group was 0.75±0.05, where as in the control group was 0.82±0.06. The Mean±SDTorg ratio of C6 cervical vertebra among the case group was 0.76±0.05, where as in the control group was 0.82±0.06.Mean±SDTorg ratio of C7 cervical vertebra among the case group was 0.76±0.05, where as in the control group was 0.82±0.06. The frequency of neurologic symptoms in study population as been detailed in Table 3. Pain was the commonest neurological symptom observed among 82 (98.8%) patients of case group, followed by Numbness, that wasobserved among44 (53%) patients. The details of clinically

confirmed cervical stenosishave been depicted in Figure 3. Majority, 78.3% (n=65) of the patients in the case group have clinically confirmed cervical stenosis in the C5 vertebra.

**Discussion**

Degenerative cervical spine illnesses reduce the important space in the spinal canal, affecting the correct function of neuronal elements at the stenosis level. Even with low-energy trauma, the chance of neurological symptoms developing increases in patients with advanced stenotic alterations. The use of Torg-ratio on the plain x-rays has been a common and inexpensive procedure. When Carrino JA et al., looked at the Torg-Pavlov ratio, they found that it had a higher sensitivity but a predictive value of low positivity. CT scans and MRIs, on the other hand, provide precise measurements of the structures of the cervical spine anatomically, preventing faults of technical issues that can result in incorrect computations.[11]

In our study, eighty-three individuals with an average age of 57.987.63 years were enrolled. This last element is frequently linked to the quantity of heavy labour performed prior to the age of 20. Previous cross-sectional investigations have shown that even in asymptomatic healthy people, age-related alterations in the cervical spine are common. Pacetti M et al., used a 0.1 MRI imager to study the cervical spine with 89 healthy participants. Abnormal findings were found in 62 percent of individuals 40 years and older, but were uncommon in subjects younger than 40 years of age.[12]

49.4 percent of the study participants are males, while 50.6 percent were females. According to Kalichman et al., a higher prevalence of cervical canal stenosis among a community-based population (59.6% of males and 6.7 percent of females), that rises with age, reaching 89.2% in people over 60. Age, sex, spinal level, facet orientation (sagittally oriented), and a history of intervertebral disc degeneration are all risk factors for cervical canal stenosis. The link between degenerative changes in the cervical canal stenosis and symptomatic low back pain, on the other hand, is uncertain and under controversy.[13]

The Sagittal spinal cord diameter (AP-SC) increases at the level of C7 (9.230.40), and the smallest sagittal diameter of the canal was observed at the level of C3 (9.050.47) in our study. Duan et al. proposed this theory in their study of vertebral artery route and function at the craniocervical junction. This observation could be a useful tool for all treating physicians, especially those performing a surgical approach on the cervical spine, because it could provide important information not only about the surgical approach (right or left), but also about the surgical technique (size and orientation of screws).[14]

The Mean Torg ratio of cervical vertebrae C3-C4 declines gradually from C3 (0.780.05) to C7 (0.760.05) in our study. The Mean Torg ratio remains constant at the C4-C7 level. Radicular pain is caused by direct compression of major nerve roots, which can occur either within the spinal canal, at their exit zones, or outside the vertebral column. Such neural compression can be caused by facet hypertrophy, localised osteophytes, rostrocoudol subluxation of facets, and

expansion of the facet joint capsule due to joint effusion. Inflammation from the facet complexes can also migrate through the myofascial areas, affecting numerous surrounding nerve roots, or a swollen joint capsule can compress an adjacent nerve root. [15]

The Transverse Vertebral Canal Diameter (T-VC) was lowest at C3 (25.001.13) and gradually increased at C6 (25.181.14) in our study. According to Molloy R et al, a study of mean values of the size of the transverse spinal foramens found that for each level of the cervical spine, males have larger sagittal and transverse foramens than females.Furthermore, at the C1 level, the sagittal diameter exceeds the transverse, whereas the transverse diameter exceeds the sagittal at all subsequent levels of the cervical spine (C2-C7). This behaviour was observed in both study groups equally (males, females). The measurements revealed that the left vertebral foramen is larger than the right one. This discrepancy was detected in both male and female patients, as well as at each level of the cervical spine, suggesting a bigger left-sided vertebral artery and possibly asymmetric blood supply of these arteries.[16]

Males had a longer distance from the spinal canal to the transverse foramens than females. The right side had a longer mean distance in between the transverse foramen and spinal canal than that of the opposite side, which is consistent with our findings showing the is larger transverse foramen on left than the right. The minimal dSC-TF level for male subjects was C5, whereas the limit for female subjects was C4. It usually causes mechanical neck pain, although it can also cause asymptomatic neck pain.

Joint facets are clinically significant generators of spinal pain, according to studies, and individuals with bothersome joint facets can benefit from certain therapies. The symptoms are often aggravated by extension and relieved by flexion, with no pain radiating below the knee. The amount of deterioration and pain have a poor association. Mechanical stress is amplified in facets that are more horizontal in the sagittal plane, such as those at the C4-C5 level. The visualization of inflammation of the facet joint and associated soft tissues is becoming increasingly important in imaging studies. This inflammation is thought to be the source of non-irradiating local pain. Bony overgrowth, on the other hand, might produce neuroforaminal constriction, resulting in irradiating pain.[17]
The fundamental demographic parameters and the prevalence of spinal canal degeneration features in the study sample with Neck pain are shown in our study. In this study, a higher prevalence of constriction of joint space (50.6%), Osteophytes (38.5%), Irregularity of articular surface (49.4%), and 2nddegree facet joint degeneration (37.3%) was observed by this study. According to Resnick Detal., Facet joint OA was linked to various degenerative characteristics of the spine, including disc narrowing, spondylolysis, degenerative spondylolisthesis, and reduced multifidus and erector spinae density. Disc narrowing was also linked to degenerative spondylolisthesis and low multifidus and erector spinae density, as well as a near-significant link to spinal stenosis. The density of multifidus and erector spinae was found to be associated with degenerative spondylolisthesis.[18]

Pain (98.8%), numbness (53.0%), tingling (25.3%), weakness (7.2%), and gait instability (7.2%) were all common neurologic complaints in our study (6 percent). (Figure 4) Despite the fact that doctors frequently consult radiologists to assess the severity of osteoarthritis at the facet joint, radiological studies that are published have found no link in between the clinical features of low back pain and spinal degenerative alterations seen on radiological examinations (Schwarzer et al. 1995). The link between degenerative alterations among the facet joints of cervical region and clinical low back pain is particularly hazy and a source of heated discussion. Osteoarthritis of cervical facets is closely related to degenerative disc disease, a separate but functionally related syndrome that affects components in the anterior spinal column.[19]

Multiple reports of a high prevalence of degenerative spinal alterations in asymptomatic persons have been found in the clinical literature, however there is no evidence of a link between these changes and the onset of neck discomfort. Owing to the enormous variety and number of possible generators of pain in the lumbar spine, diagnosing and treating neck pain remains difficult. The majority of research focuses on the intervertebral discs; nevertheless, it is becoming clear that the zygapophysial jointplays a significant role in low back pain. Spinal painmediatedby facets is hard to diagnose. The facet joint may be the source of pain based on the history and physical examination, but this cannot be confirmed.[20]

The degenerative alterations progressed in 81.1 percent of the originally asymptomatic individuals, according to this longitudinal investigation. During follow-up, however, 15% of the individuals reported neck pain. The discs and facet joints are vital for both biomechanical load shift and cervical spine movement. Facet joints are thought to be the most common source of pain in post-traumatic persistent neck discomfort. Other anatomical structures, such as intervertebral discs, may be affected as well. Cervical spondylosis is thought to have a negative impact on the prognosis following neck injuries.[21]

**Limitations**

The study's ability to aid clinical decision-making is severely limited by the lack of precise information on neck pain severity, frequency, and functional limitations. However, we feel the study's message is to emphasize that degenerative signs are frequently seen with modern imaging techniques, such as CT, and that caution should be exercised before determining that such features are pathogenic. The study's design also has some significant flaws, such as the lack of medical confirmation of patient-reported symptoms and a small sample size.

**Conclusion**

The conventional lateral plain x-ray technique can be replaced with a Computed Tomography scan, which could offer appropriate measures of cervical canal that can be used as a tool in determining cervical canal stenosis. More research is needed for applying the ratio of Torg-Pavlov to further precise CT scans of cervical region. Furthermore, our measurements of transverse foramen diameters may provide important information to spinal surgeons about the foramen's geometrical

changes and dimensions as a function at the level of cervical region, promoting planning of preoperative setting and preventing likely trauma to vertebral arteries at the time of tissue dissection and application of instruments.

**References**


1. Bernhardt M, Hynes RA, Blume HW, White 3rd AA: Cervical spondyloticmyelopathy. J Bone Joint Surg Am. 1993, 75:119-128. 10.2106/00004623-199301000-00016
2. Bernhardt M, Hynes RA, Blume HW, White AA III. Cervical spondyloticmyelopathy. J Bone Joint Surg Am. 1993; 75:119–128
3. Brett A Freedman, et al. A Comparison of Computed Tomography Measures for Diagnosing Cervical Spinal Stenosis Associated with Myelopathy: A Case-Control Study. Asian Spine Journal 2015;9(1):22-29.
4. Carrino JA, Lurie JD, Tosteson AN, Tosteson TD, Carragee EJ, Kaiser J, Grove MR, Blood E, Pearson LH, Weinstein JN, Herzog R. Lumbar spine: reliability of MR imaging findings. Radiology. 2009;250(1):161-70.
5. Cook C, Braga-Baiak A, Pietrobon R, Shah A, Neto AC, de Barros N: Observer agreement of spine stenosis on magnetic resonance imaging analysis of patients with cervical spine myelopathy. JManipulativePhysiol ther.2008, 31:271-276. 10.1016/j.jmpt.2008.03.006
6. Gellhorn AC. Cervical facet-mediated pain. Phys. Med. Rehabil. Clin. N. Am. 2011; 22:447–458.
7. Gore DR. Roentgenographic findings in the cervical spine in asymptomatic persons: a ten-year follow-up. Spine (Phila Pa 1976). 2001; 26:2463–66.
8. Ilyas M. DislokasiInterfasetal Bilateral. [Bilateral Interfacetal Dislocation]. J Med Nus 2005;24: 127-34.
9. Jeffrey S. Stafira, Jafgadeesh R. Sonnad, William T. C. Yuh, David R. Huard, Robin E. Acker, Dan L. Nguyen, Joan E. Maley, Faridali G. Ramji, Wen-Bin Li, Cjhristopher M Loftus American Journal of Neuroadiology2003; 24 (4) 766-769.
10. Jones ET, Mayer P. Turek'sOrthopedics, Principles and Their Application, 5th ed. J.B. Lippincott Company Philadelpia, 1994. pp 345-6.
11. Kalichman L, et al. Facet joint osteoarthritis and low back pain in the community-basedpopulation. Spine (PhilaPa1976) 2008; 33:2560–2565.
12. Kalichman L, Li L, Kim DH, Guermazi A, Berkin V, O'Donnell CJ, Hoffmann U, Cole R, Hunter DJ. Facet joint osteoarthritis and low back pain in the community-based population. Spine (Phila Pa 1976). 2008 Nov 1;33(23):2560-5.
13. Kang Y, Lee JW, Koh YH, Hur S, Kim SJ, Chai JW, Kang HS: New MRI grading system for the cervical canal stenosis. AJR Am J Roentgenol. 2011,197:134-140. 10.2214/AJR.10.5560
14. Lewinnek GE, Warfield CA. Facet joint degeneration as a cause of low back pain. Clin. Orthop. Relat. Res. 1986; 213:216–222.
15. Nagata K, Yoshimura N, Muraki S, et al.: Prevalence of cervical cord compression and its association with physical performance in a population-based cohort in Japan: the Wakayama Spine Study. Spine. 2012, 37:1892-1898.

16. Pacetti M, Fiaschi GS, Gennaro S. Percutaneous radiofrequency thermocoagulation of dorsal ramus branches as a treatment of Blumbar facet syndrome^ how I do it. Acta Neurochir (Wien) 2016;158(5):995–998.
17. PalG,RoutalR,SagguS.The orientation of the articular facet of the zygapophyseal joints at the cervical and upper thoracic region.Journal of Anatomy. 2001; 198(4): 431-441. doi:10.1017/S0021878202007373.
18. Pathria M, Sartoris DJ, Resnick D. Osteoarthritis of the facet joints: accuracy of oblique radiographic assessment. Radiology. 1987; 164:227–230.
19. Schwarzer AC, Aprill CN, Derby R, Fortin J, Kine G, Bogduk N. Clinical features of patients with pain stemming from the lumbar zygapophysial joints. Is the lumbar facet syndrome a clinical entity? Spine. 1994;19:1132–1137.
20. Torg JS et al. Cervical cord neurapraxia: classification, pathomechanics, morbidity, and management guidelines. J Neurosurg 1997;87(6):843-50
21. Yarbrough CK, Murphy RK, Ray WZ, Stewart TJ: The natural history and clinical presentation of cervical spondylotic myelopathy. Adv Orthop. 2012, 2012:480643. 10.1155/2012/480643