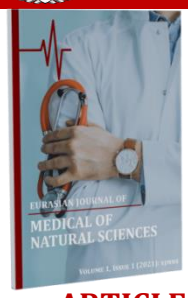
EURASIAN JOURNAL OF MEDICAL AND NATURAL SCIENCES
Innovative Academy Research Support Center
IF = 7.921 www.in-academy.uz



CT SEMIOTICS OF VERTEBRAE IN PATIENTS WITH CERVICAL SPINAL STENOSIS

Parvoz Abdulhakimov
Samarkand state medical university, Samarkand, Uzbekistan
https://doi.org/10.5281/zenodo.15920376

ARTICLE INFO

Received: 08th July 2025
Accepted: 14th July 2025
Online: 15th July 2025

KEYWORDS

Spine, cervical spine, stenosis, semiotics, CT

ABSTRACT

Introduction. *The number of surgical interventions on the cervical spine due to stenosis is constantly increasing, which justifies the need for careful preoperative preparation, taking into account the complexity of the intervention and the age of the patients.*

The purpose of the work *is to justify the need to include in the algorithm for processing CT data the density of bone tissue of the vertebral bodies and arches to assess its quality when planning osteoplastic decompressive surgery. Laminoplasty in patients with cervical spine stenosis against the background of degenerative-dystrophic changes.*

Materials and methods. *Single-center retrospective study. Qualitative and quantitative characteristics of the spine were studied using radiography and multislice computed tomography (MSCT) in 82 patients with degenerative-dystrophic diseases of the cervical spine with spinal canal stenosis (SCS).*

Results. *The data obtained indicate a tendency to increase the overall density of the cervical vertebrae from CIII to CV and to decrease it more caudally with a minimum density for CVII without signs of osteoporosis. A similar tendency is characteristic of the trabecular bone. The density of the osteon layer of the cortical plate of the vertebral arch significantly differs from the density of the outer and inner plates. The total density of the compact layer of the cortical plate of the vertebral arch exceeds (785.15 ± 38.4) HU.*

Discussion. *In patients with degenerative-dystrophic changes in the spine, the assessment of the density of various structural formations of the vertebrae according to CT data should be given the greatest importance. First of all, bone density assessment becomes increasingly important with the age of patients. Determining the bone quality is crucial for the success of treatment, but it is also part of the optimal surgical preparation for spinal surgery.*

INTRODUCTION

Modern imaging techniques provide excellent anatomical images of the cervical spine. The choice of each depends on the clinical scenario and therapeutic alternatives. Multipositional radiography still remains a fundamental method, as it allows for evaluation of the spinal axis, vertebral dimensions and changes, and for follow-up after treatment, being cost-effective and visually justified examination [1–3]. The role of MRI has significantly increased, allowing visualization of soft tissue structures of the spine, including intervertebral discs, ligaments, spinal cord, in particular, its mobility, which is extremely important for patients with cervical spinal stenosis (CSSS) complicated by myelopathy [2, 4–8]. No less importance is attached to multislice computed tomography (MSCT) in the study of degenerative changes in the spine due to its high spatial resolution and unique ability to qualitatively and quantitatively assess the condition of the vertebrae, both before treatment and at its various stages [2, 9, 10]. A set of radiation diagnostic methods is often used to assess the results of treatment of patients with CSSS [2, 11]. The study of the anatomy of the vertebrae, their architecture, and density indices is extremely important for deciding on the choice of treatment method for any type of surgical intervention on the spine, including the elimination of cervical spinal stenosis (CSSS). Determining the quality of the bone is of crucial importance for the success of treatment in many cases, but it is also part of optimal surgical preparation for spinal surgery [12, 13]. First of all, this concerns the assessment of the bone condition for the introduction of implants for various types of transpedicular fixation and other methods of metal osteosynthesis in order to prevent various complications associated with malposition of screws or other structures, failure of metal structures, and more attention should be paid to patients with pronounced degenerative changes in density indices (HU) [14–16]. Bone density, as an important strength factor, is determined by various methods, but the most common and universal is MSCT using standardized Hounsfield units (HU), providing a reliable assessment of bone density, improving diagnostic indicators [10, 18, 19]. The study of the anatomy, architecture, and density of the vertebrae is carried out using individual methods or in a complex, as in the work of G. Schröder et al., where micro-CT and MSCT were used [12]. Histomorphometric study (the “gold standard” for studying bone quality) in the work of HJ Grote et al. was used to assess trabecular bone density [20]. In cases where CT is used, cancellous bone density in HU is determined for the C2–C7 vertebrae on each sagittal, coronal and axial CT image, and cervical spine (CS) computed tomography results provide reliable information regardless of the plane of measurement, age or gender, and the degree of degeneration [21]. According to Q. Zaidi et al., O.N. Leonova et al., in patients with degenerative-dystrophic changes in the spine, the greatest importance should be attached to the assessment of the density of various structural formations of the vertebrae according to MSCT data [15, 22]. In the literature presented above, concerning the determination of the quality of the vertebral bone based on bone density according to MSCT data, only some indicators and parameters of the vertebral body have been studied, and when measuring mainly the local density of spongy bone. However, it is important to know the state of all structural formations of the vertebra, especially when using the laminoplasty method, where the most important anatomical zones for the surgeon are the vertebral arches and facet joints, as the main objects to which the plates are fixed. The purpose of the work is to substantiate the need to include in the algorithm for processing MSCT data the density of bone

tissue of the vertebral bodies and arches to assess its quality when planning osteoplastic decompressive surgery laminoplasty in patients with cervical spinal stenosis against the background of degenerative-dystrophic changes.

MATERIALS AND METHODS

A single-center retrospective study was performed at the neurosurgical department No. 3 Federal Center of Neurosurgery (Tyumen). Qualitative and quantitative characteristics of the spine were studied using radiography and MSCT methods in 82 patients with degenerative - dystrophic diseases of the cervical spine with spinal canal stenosis. Level of evidence - IV. Clinical and statistical characteristics of patients The presented sample was dominated by males (86.6%) aged 56 to 75 years (70.7%). The majority of patients (89.0%) had multilevel spinal stenosis (Table 1). During surgery, cervical laminoplasty was performed at the CIII–CVI and CIII–CVII levels in 68.3% of patients.

Research methods

1. Multipositional and functional radiography was performed on all 82 patients.

2. Multislice spiral computed tomography (MSCT) was performed on all 82 patients using an Aquilion X-ray computed tomograph One (1385 Shmoishigami, Otawara-shi, Tochigi 324-8550, Japan, 320 detector lines, maximum number of slices — 640). MSCT was used to assess bone quality (density, structure, size of the vertebral body and arches). Vertebral density was measured on axial and sagittal slices (total density, density of spongy bone, compact layer). The density of the cortical plate of the vertebral arch was studied in different layers. When necessary, 3D reconstructions were performed (Fig. 1). Inclusion criteria: 1) cervical spine stenosis according to MSCT and MRI data, complete radiation archive; 2) no history of cervical spine surgeries in the patients' anamnesis; 3) patients' consent to publication of the data obtained during the study, without personal identification. The study was carried out in accordance with the ethical standards of the Helsinki Declaration of the World Medical Association as amended by the Ministry of Health. All patients signed informed consent for the publication of data without personal identification. To confirm the conclusions about the differences between the results obtained in the two groups, taking into account the small samples, the Mann-Whitney U-test was used. The sample parameters given in the tables below had the following designations: M is the mean, σ is the standard root-mean-square deviation, n is the number of patients, p is the achieved significance level. The critical significance level when testing statistical hypotheses in this study was taken to be 0.05.

RESULTS

The study of the total density of the vertebrae from CIII to CVII in the sagittal plane showed its increase from the level of CIII to CIV, and from the level of CV and caudally a decrease in the indices in descending order with a minimum at the level of CVII was noted. Measurement of the density of the compact layer of the vertebral body in the sagittal plane along the anterior and posterior surfaces showed that the density of the compact layer of bone tissue was higher in the posterior parts of the vertebral bodies compared to the anterior ones, but without reliable differences. This is due to the fact that the boundaries of the compact layer and trabecular bone on axial sections are clearly visualized, whereas in the sagittal plane the boundaries are determined conditionally. When studying the density of the compact layer of the cervical vertebrae along the anterior and posterior surfaces in axial density the differences

are reliable, except for CVII. As for the CVII vertebra, it had minimal density with resorption zones and minimal differences on the anterior and posterior surfaces, due to which the density indicators did not differ.

The local total and point density of the three layers of the cortical plate was also studied, since the density of the osteonic (central) layer was much higher than the density of the outer and inner plates, which must be taken into account during preoperative measurement of the density of the vertebral arch to which the plates are fixed during laminoplasty.

Statistical data on the density of different layers of the cortical plate of the vertebral arch are shown in Figure 4. The density of the osteon layer is 33.3% higher than the density of the inner plates and 10.4% higher than the density of the outer plates. This should be taken into account when measuring the density of the cortical plate of the arch. When measuring in the area of the inner plates, the layer of which is thinner than the osteon layer, very low density values can be obtained. It is necessary to measure the density of all layers not only pointwise, but also by determining the local total density of all layers of the cortical plate, which was measured in the zone of interest in the form of a circle capturing the entire thickness of the cortical plate (ROI = 1.5–2.2 cm2). The local density of all layers of the cortical plate of the vertebral arch varied from 700 to 1150 HU, averaging (785.15 ± 38.4) HU, with the density in the zone adjacent to the facet joints being somewhat higher in 75.6% of patients. Measurement of the thickness of the vertebral arches in the axial plane at an equal distance from the central axis of the vertebra revealed that in 83% of patients this indicator differed on the right and left, with the thickness being smaller on the right in 45% of patients.

DISCUSSION

The use of MSCT allowed us to determine not only the nature and prevalence of changes in the spine, but also to study the quantitative density characteristics of the vertebrae in SSOP, which allowed us to objectively judge the state of trabecular and compact bone tissue when assessed in Hounsfield units (HU). This conclusion is confirmed by the studies of A.N. Mikhailov, T.N. Lukyanenko [23]. In the work of G. Schröder et al . using micro-CT and MSCT in all examined patients, the density of cancellous bone was significantly higher in the cervical vertebrae (mean 177.6 HU) than in the thoracic (mean 94.4 HU) or lumbar vertebrae (mean 62.8 HU, $p < 0.001$). In our study, the density of the vertebrae in the cervical region was significantly higher than in the presented data. This is due to the fact that in the cited work, patients with one or two vertebral fractures at the age of (84.3 ± 8.4) years were examined, whereas in our sample the average age did not exceed (58.9 ± 7.9) years, and there were no patients with vertebral fractures. In addition, we studied the trabecular bone density over the entire area of the vertebra in the axial plane, whereas the authors studied a small area in the center of the vertebra, which did not always reflect the overall density [24]. Histomorphometric study (the " gold standard " for studying bone quality) HJ Grote et al . found that the trabecular bone density in the cervical spine is significantly higher than in the thoracic or lumbar spine [20]. It was shown that bone loss in the cervical spine with age is less than in other parts of the spine. No significant age-related loss of trabecular density was noted in the CIII and CIV cervical vertebrae, which is consistent with the data of G. Schröder et al. [24, 25]. In studies using CT, the density of cancellous bone in HU was determined for the CII–CVI vertebrae on each sagittal, coronal and axial CT image [21]. According to the authors, the average density

values in units The Hounsfield (HU) values, which can be attributed to osteopenia and osteoporosis, were (284.0 ± 63.3) and (231.5 ± 52.8), respectively. The density indices of the two upper cervical vertebrae (CII and CIII) had a higher density than for other segments [21]. According to our data, the trabecular density of the vertebrae was much higher, averaging (387.89 ± 49.14) to (333.81 ± 46.09) for CIII–CVI. We also studied the density of different layers of the cortical plate of the vertebral arch, which is an important object of the surgical scenario. The highest density corresponded to the osteonic layer, which coincides with the data of G.V. Dyachkova et al. [26]. The local density of all layers of the cortical plate of the vertebral arch varied from 700 to 1150 HU, averaging (785.15 ± 38.4) HU. According to Q. Zaidi et al ., in patients with degenerative-dystrophic changes in the spine, the greatest importance should be attached to the assessment of the density of various structural formations of the vertebrae using MSCT data [15]. First of all, the assessment of bone density becomes increasingly important with the age of patients. Determination of bone quality is crucial for the success of treatment, especially the prevention of osteoporotic fractures, but it is also part of optimal surgical preparation for spinal surgery and monitoring the condition of screws [24, 27]. The data obtained indicate a tendency for the overall density of the cervical vertebrae to increase from CIII to CV and decrease further caudally with minimal density for CVII without signs of osteoporosis. A similar trend is characteristic of the trabecular bone. According to X. Liang et al ., it is necessary to determine not only the overall and local density of the vertebrae, but also to study it at three levels in the sagittal plane (upper third , central part, lower third) to clarify the effect of disc degeneration on the density of the vertebra [28]. Reliable differences in the density of compact bone along the posterior surface of the CIII–CV vertebrae were revealed on axial sections. There is a moderate asymmetry in the thickness of the vertebral arch on axial sections. The density of the osteon layer of the cortical plate of the vertebral arch differs significantly from the density of the outer and inner plates. The overall density of the compact layer of the cortical plate of the vertebral arch exceeds 785.15 ± 38.4 HU, which indicates sufficient density of the vertebral arch, taking into account all its layers, for the safe insertion of fixing screws.

CONCLUSION

The obtained data substantiate the need to include in the MSCT data processing algorithm the study of the density of the vertebral bodies, the vertebral arch, its thickness for developing a plan for surgical intervention in patients with cervical spinal stenosis, since they allow obtaining an objective characteristic of bone quality.

References:

1. Damdinov B.B., Sorokovikov V.A., Larionov S.N., et al. Features of changes in the sagittal balance of the cervical spine in cervicobrachial syndrome. Spine surgery. 2019;16(2):42-48. doi: 10.14531/ ss2019.2.42-48
2. Spirig JM, Sutter R, Götschi T, et al. Value of standard radiographs, computed tomography, and magnetic resonance imaging of the lumbar spine in detection of intraoperatively confirmed pedicle screw loosening—a prospective clinical trial. Spine J. 2019;19 (3):461-468. doi: 10.1016/j.spinee.2018.06.345
3. Hirai T, Yoshii T, Sakai K, et al. Long-term results of a prospective study of anterior decompression with fusionand posterior decompression with laminoplasty for treatment of

cervical spondylotic myelopathy. J Orthop Sci. 2018;23(1):32-38. doi: 10.1016/j.jos.2017.07.012

4. Wolf K, Krafft AJ, Egger K, et al. Assessment of spinal cord motion as a new diagnostic MRI-parameter in cervical spinal canal stenosis: study protocol on a prospective longitudinal trial. J Orthop Surg Res. 2019 ;14 (1):321. doi: 10.1186/ s13018-019-1381-9

5. Hesni S, Baxter D, Saifuddin A. The imaging of cervical spondylotic myeloradiculopathy. Skeletal Radiol. 2023;52 (12):2341-2365. doi: 10.1007/s00256-023-04329-0

6. Tetreault L, Kalsi-Ryan S, Davies B, et al. Degenerative Cervical Myelopathy: A Practical Approach to Diagnosis. Global Spine J. 2022 ;12 (8):1881-1893. doi: 10.1177/21925682211072847

7. Chen YC, Kuo CH, Cheng CM, Wu JC. Recent advances in the management of cervical spondylotic myelopathy: bibliometric analysis and surgical perspectives. J Neurosurg Spine. 2019;31 (3):299-309. doi: 10.3171/2019.5. SPINE18769

8. Nouri A, Cheng JS, Davies B, et al. Degenerative Cervical Myelopathy: A Brief Review of Past Perspectives, Present Developments, and Future Directions. J Clin Med. 2020;9 (2):535. doi: 10.3390/jcm9020535

9. Llopis E, Belloch E, León JP, et al. The degenerative cervical spine. Radiologia. 2016 ;58 Suppl 1:13-25. doi: 10.1016/j.rx.2015

10. Xu F, Zou D, Li W, et al. Hounsfield units of the vertebral body and pedicle as predictors of pedicle screw loosening afterdegenerative lumbar spine surgery. Neurosurg Focus. 2020;49 (2):E10. doi 10.3171/2020.5. FOCUS20249

11. Liu FJ, Ding XK, Chai Y, et al. Influence of fixed titanium plate position on the effectiveness of open-door laminoplasty for cervical spondylotic myelopathy. J Orthop Surg Res. 2022 ;17 (1):297. doi: 10.1186/s13018-022-03188-0

12. Schröder G, Reichel M, Spiegel S, et al. Breaking strength and bone microarchitecture in osteoporosis: a biomechanical approximation based on load tests in 104 human vertebrae from the cervical, thoracic, and lumbar spines of 13 body donors. J Orthop Surg Res. 2022 ;17 (1):228. doi: 10.1186/s13018-022-03105-5

13. Kim MK, Cho HJ, Kwak DS, You SH. Characteristics of regional bone quality in cervical vertebrae considering BMD: Determining a safe trajectory for cervical pedicle screw fixation. J Orthop Res. 2018 ;36 (1):217-223. doi: 10.1002/jor.23633

14. Zeynalov Yu . L., Dyachkova G. V., Burtsev A. V. and dr. Computed tomographic semiotics of apical vertebrae in patients with idiopathic scoliosis aged 14 to 18 years depending on the magnitude of spinal deformity. Radiology – practice. 2021; (5):11-27. doi: 10.52560/2713-0118-2021-5-11-27

15. Zaidi Q, Danisa OA, Cheng W. Measurement Techniques and Utility of Hounsfield Unit Values for Assessment of Bone Quality Prior to Spinal Instrumentation: A Review of Current Literature. Spine (Phila Pa 1976). 2019 ;44 (4): E239-E244. doi: 10.1097/BRS.0000000000002813

16. Han C, Zhou C, Zhang H, et al. Evaluation of bone mineral density in adolescent idiopathic scoliosis using a three-dimensional finite element model: a retrospective study. J Orthop Surg Res. 2023 ;18 (1):938. doi: 10.1186/s13018-023-04413-0

17. Weinberg DS, Rhee JM. Cervical laminoplasty: indication, technique, complications. J Spine Surg. 2020 ;6 (1):290-301. doi: 10.21037/jss.2020.01.05
18. Choi MK, Kim SM, Lim JK. Diagnostic efficacy of Hounsfield units in spine CT for the assessment of real bone mineral density of degenerative spine: correlation study between T-scores determined by DEXA scan and Hounsfield units from CT. Acta Neurochir (Wien). 2016 ;158 (7):1421-1427. doi: 10.1007/s00701-016-2821-5
19. Wang H, Zou D, Sun Z, et al. Hounsfield Unit for Assessing Vertebral Bone Quality and Asymmetrical Vertebral Degeneration in Degenerative Lumbar Scoliosis. Spine (Phila Pa 1976). 2020 ;45 (22):1559-1566. doi: 10.1097/ BRS.0000000000003639
20. Grote HJ, Amling M, Vogel M, et al. Intervertebral variation in trabecular microarchitecture throughout the normal spine in relation to age. Bone. 1995 ;16 (3):301-308. doi: 10.1016/8756-3282(94)00042-5
21. Han K, You ST, Lee HJ, et al. Hounsfield unit measurement method and related factors that most appropriately reflect bone mineral density on cervical spine computed tomography. Skeletal Radiol. 2022;51(10):1987–1993. doi: 10.1007/ s00256-022-04050-4
22. Leonova ON, Baikov ES, Krutko AV. Features of bone density of the lumbar vertebrae in patients with degenerative diseases of the spine. Genius of Orthopedics. 2022;28(5):692–697. doi: 10.18019/ 1028-4427-2022-28-5-692-697. EDN: EUHAVU.
23. Mikhailov AN, Lukyanenko TN. Mineral density of the vertebrae in patients with cervical osteochondrosis according to quantitative computed tomography. International Reviews: Clinical Practice and Health. 2014;(6):24-32.
24. Schröder G, Jabke B, Schulze M, et al. A comparison, using X-ray micro-computed tomography, of the architecture of cancellous bone from the cervical, thoracic and lumbar spine using 240 vertebral bodies from 10 body donors. Anat Cell Biol. 2021;54(1):25-34. doi: 10.5115/acb.20.269
25. Schröder G, Wendig D, Jabke B, et al. Comparison of the spongiosa morphology of the human cervical spine (CS), thoracic spine (TS) and lumbar spine (LS) of a 102-year-old body donor. Osteology. 2019;28(04):283-288. (In German) doi: 10.1055/a-0997-8059
26. Dyachkov KA, Dyachkova GV, Kutikov SA Method for determining the local density of the cortical plate of long bones. Russian Federation Patent for Invention No. 2539424. 20.01.15. Bulletin No. 2. Available at: https://www.fips.ru/registers-doc-view/fips_servlet. Link active on 07.02.2024.
27. Wu X, Shi J, Wu J, et al. Pedicle screw loosening: the value of radiological imaging and the identification of risk factors assessed by extraction torque during screw removal surgery. J Orthop Surg Res. 2019 ;14 (1):6. doi: 10.1186/s13018-018-1046-0
28. Liang X, Liu Q, Xu J, et al. Hounsfield Unit for Assessing Bone Mineral Density Distribution Within Cervical Vertebrae and Its Correlation With the Intervertebral Disc Degeneration. Front Endocrinol (Lausanne). 2022;13:920167. doi: 10.3389/fendo.2022.920167