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Research Article

Investigation of the Relationship Between Cervical Vertebral Column Degeneration and Posterior Circulation Perfusion Area Ischemia

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Abstract

Aim: The primary objective of this study was to establish whether degeneration of the cervical vertebrae and paravertebral structures serves as a predisposing factor for ischemic processes by disrupting hemodynamics in the posterior system through mechanical effects on the vertebral arteries.

Material and Method: We conducted a retrospective analysis of 180 patients who underwent various imaging tests between January 2017 and October 2023. These tests included cervical magnetic resonance imaging (MRI), cervical computed tomography (CT), carotid-vertebral neck CT angiography (CTA), cranial CT, and cranial MRI. Of the 180 patients, 90 had mild degeneration or no significant degeneration, with a mean age of 58 years, and 90 had significant cervical spondylosis (CS) with a mean age of 64 years. The radiological findings were statistically analyzed, and a p-value of less than 0.05 was considered statistically significant.

Results: There was no significant difference between age and parenchymal density in the control group (p=0.09). There was no statistically significant difference between the age and parenchymal density in the CS group (p=0.07). As CS became more severe, there was a statistically significant increase in the incidence of atrophic enlargement of the cerebellar folia and loss of density in the posterior fossa (p=0.03) and posterior circulation infarcts (POCI) (p=0.04).

Conclusion: When severe, CS can adversely affect vascular hemodynamics in the posterior system, predisposing perfused neural parenchyma to ischemia.

Keywords: Paravertebral structures, posterior circulation, vertebrae degeneration, vertebral artery

INTRODUCTION

Spinal degeneration is terminologically defined as "spondylosis" (1,2). Cervical spondylosis (CS) is typically observed in middle-aged and elderly individuals. It is the most common cause of progressive spinal cord and nerve root compression (3,4). The majority of patients with CS are asymptomatic, and the most common initial finding in symptomatic patients is neck pain and limitation of neck movement, which occur due to cervical misalignment and neural compression (5). Patients usually do not know the exact time of onset of symptoms (6). The most common complaint is weakness and loss of dexterity in the upper extremities (7).

Acute ischemic stroke in young patients is often attributed to arterial dissections (8). In contrast, the chronic ischemic processes observed in middle-aged and elderly patients may be caused by the narrowing of the arteries due to atherosclerosis, compression of the external lumen due to degeneration, and hemodynamic negativities in addition to secondary stenosis (9). The vertebral artery originates from the posterior superior part of the subclavian artery on both sides, enters the transverse foramen at the level of the C6 cervical spine (7.5% from C7), and extends upward within these canals (10). The widespread use of radiological imaging modalities has revealed the more frequent occurrence of chronic ischemic findings in the neural parenchyma of the posterior fossa perfused by the posterior circulation in middle-aged and elderly populations (11,12).

In cases of severe CS, the vertebral artery may not be compressed significantly when the patient is stable, or even if it is compressed, the arterial system originating from the posterior circulation and perfused neural parenchyma may compensate for the hemodynamic abnormality in the long term. However, since the cervical spine is a highly unstable and mobile anatomical body part in daily life, the compression to which the vertebral arteries may be

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exposed may change rapidly. Therefore, the autonomic nervous system may not be able to compensate for the lack of perfusion that may result from this (13).

In our study, we aimed to quantitatively determine the chronic ischemic process that may be caused by hemodynamic disturbances originating from the vertebrobasilar system in patients with CS by qualitatively detecting ischemic areas in the posterior fossa on cranial MRI and measuring the density in Hounsfield Units (HU) on computed tomography (CT) from the same location.

MATERIAL AND METHOD

Ethics Committee Approval

Our study was conducted at the Department of Radiology of BHT Clinic İstanbul Tema Hospital, with the approval and permission of the Academic Board and Ethics Committee of Nişantaşı University (date: 14.08.2023, decision No: 13). Our study was retrospectively based on radiologic imaging evaluation, and the procedures were performed in accordance with the Declaration of Helsinki and its amendments.

Study Population

This study included cervical magnetic resonance imaging (MRI), cervical CT, neck CT angiography (CTA), and radiological images of 180 patients who underwent concurrent brain CT and brain MRI examinations between January 2017 and October 2023. Poor quality images were excluded. Patients with a history of intracranial surgery, severe cerebral ischemia, cerebral hemorrhage, vertebral artery occlusion, and/or significant stenosis were excluded. Patients examined between January 2017 and October 2023 were screened according to inclusion and exclusion criteria. Data collection was initiated for 180 eligible patients.

Ninety patients with mild or no significant degeneration were included in the control group, with a mean age of 58 years. In this group, 44 were female and 46 were male; the youngest was 48 years old and the oldest was 62 years old (Table 1).

The remaining 90 patients had moderate and prominent CS, 40 of whom were female and 50 were male with a mean age of 64 years. The youngest patient in this group was 56 years old, and the oldest was 66 years old (Table 1).

Table 1. Age and gender distribution of patients

Patients	Control group	CS
Gender	Female/male	
	44/46	40/50
Age(years)	Minimum/maximum	
	48/62	56/66
	Mean	
	58	66

CS: cervical spondylosis

Obtaining Radiologic Images and Study Design

The images of the patients included in our study were retrospectively evaluated using a radiological image storage system (picture archiving and communication system, PACS) at the hospital where the study was performed. There were 2 CT devices used in the hospital, the first was a General Electric (GE) Brightspeed 16 detector Multislice CT (GE, Waukesha, Wisconsin, USA) and the second was a GE Revolution GSI 256 detector Multislice CT (GE, Waukesha, Wisconsin, USA). Similarly, the patients examined in our study were examined using two MRI devices, the first of which was a GE Signa HDe 1.5 Tesla (GE, Waukesha, Wisconsin, USA). Coil: HD 8 channel NV array coil (In vivo Corporation, Gainesville, Florida, USA)). Our second device had more advanced features: GE Signa Architect 3 Tesla (GE, Waukesha, Wisconsin, USA). Coil: 3.0T GEM HNU 19HN+PA NV coil (GE, Aurora, Ohio, USA)). There was no significant difference between these two different CT and MRI devices in terms of their performance and capacity to evaluate patients, detect pathologies, and measure quantitative values in terms of CT density.

Radiologic images of patients who were examined between January 2017 and October 2023 were transferred from the hospital closed-circuit image storage network to the software interface Clear Canvas via PACS and evaluated retrospectively.

Cervical CT and neck CTA images were evaluated using multiplanar reconstruction (MPR) on axial (normal raw data), sagittal, and coronal (MPR-enhanced plans) images. In the CT examinations, osteophyte and facet hypertrophy, especially of bony origin, were evaluated.

In cervical MRI examination, standard sagittal spin echo (SE) T1 and T2 and axial SE T2 sequences were obtained. Uncovertebral degeneration and degenerative findings in the ligaments and paravertebral soft tissues were evaluated using MRI.

Vertebral corpus corner osteophytic tapering and degenerative signal changes in the endplates (classified by Modic typing) on MRI examination are indicative of cervical degeneration.

Modic Degeneration Changes are Divided into Three Types

In the type 1 cases, edema and inflammation were observed in the bone marrow. In type 2, normal bone marrow cells are transformed into yellow fatty bone marrow cells due to ischemia. Type 3 indicates subchondral bone sclerosis. In addition, mixed types, in which type 1, type 2, type 2, and type 3 are observed together may also be observed (14).

We classified the patients with spinal degeneration as mild, moderate, or severe. We classified patients with mild degeneration as those with minimal cervical osteophytes at only one or a few vertebral levels, Schmorl's nodules on vertebral endplates, and mild degenerative signal changes on MRI (especially Modic type 1 and type 2 degeneration). These patients exhibited minimal degenerative changes in the intervertebral discs at one or two levels. Those with moderate degeneration included those with significant flattening of the cervical lordosis at the level of three to four vertebrae, osteophytes involving the anterior

longitudinal ligament (ALL) and occasionally extending into the spinal canal, and degenerative changes in the facet joints. In addition, cervical MRI scans of these patients mostly showed Modic type 2 degeneration. In terms of intervertebral disc degeneration, mild volume loss at two or three levels and signal loss on MRI T2 sequence were observed. Patients with severe degeneration showed degeneration at almost all the vertebral levels. In addition, cervical lordosis was mostly reversed and kyphosis developed in these patients. In addition, syndesmophyte formation was present at all levels, ALL was largely eliminated, and intervertebral disc degeneration and herniation were present at almost all levels. Although not relevant, a narrow canal (cervical spinal stenosis) was present. Some patients could not be fully classified and were included in the group in which the characteristics of the group were more predominant, and the difficulty caused by this situation is expressed in the limitations section.

The patients in the control group were mostly normal and had mild, if any, spondylosis (Figure 1), whereas the other 90 patients in the pathology sample of the study had moderate (Figure 2) and severe (Figure 3) CS.

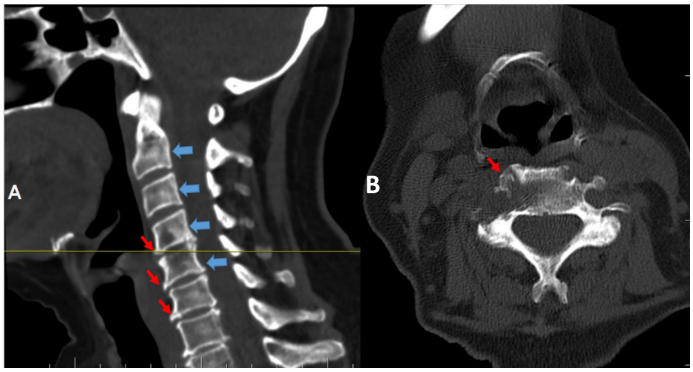

Figure 1. Cervical CT image of one patient. Left (**A**) is a cervical CT image obtained by MPR in the sagittal plane and right (**B**) is a cervical CT section image in the axial plane. Examination was performed using a bone window. In A, the thin horizontal yellow line indicates the level of the slice on the right side. In images A and B, the red arrows indicate the cervical osteophytes. When the blue arrows are followed in A, it is observed that the cervical lordosis is flattened. These findings were consistent with mild cervical degenerative changes.

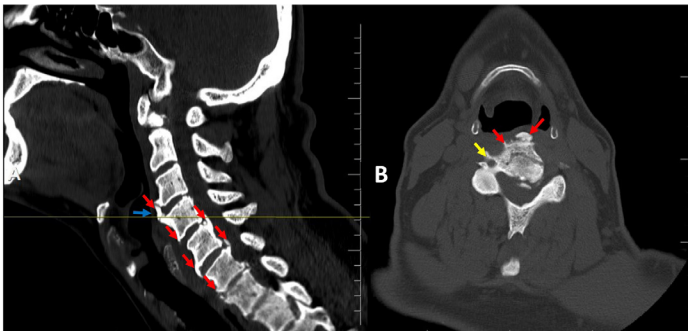

Figure 2. Cervical CT image of one patient. Left (**A**) shows a cervical CT image obtained by MPR in the sagittal plane and right (**B**) shows a cervical CT slice image in the axial plane. Examination was performed using a bone window. In A, the thin horizontal yellow line indicates the level of the slice on the right side. The red arrows in panels A and B indicate cervical osteophytes. The blue arrow in A indicates the ALL with an elongated appearance. B, Yellow arrow indicates the transverse foramen. These findings were consistent with moderate cervical degenerative changes.

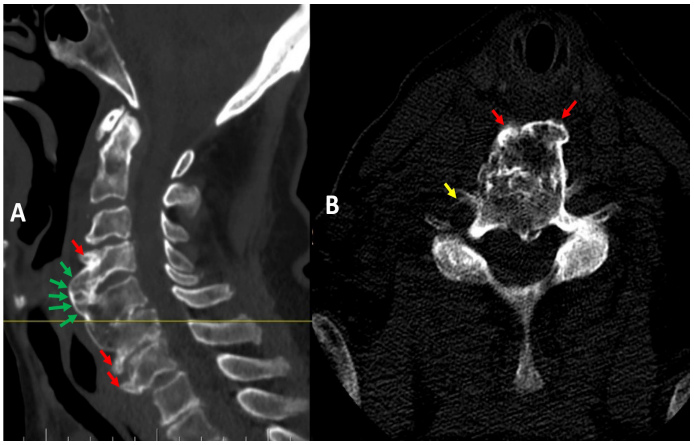

Figure 3. Cervical CT image of one patient. Left (**A**) is a cervical CT image obtained by MPR in the sagittal plane and right (**B**) is a cervical CT section image in the axial plane. Examination was performed using a bone window. In A, the yellow line indicates the level of the slice on the right-hand side. In images A and B, the red arrows indicate the cervical osteophytes. In A, the green arrows indicate syndesmophytes. B, Yellow arrow indicates the transverse foramen. These findings are consistent with those of advanced cervical degenerative changes.

The vertebral arteries of the patients were evaluated using axial raw images and MPR sagittal and coronal images derived from contrast-enhanced neck CTA scans (Figure 4).

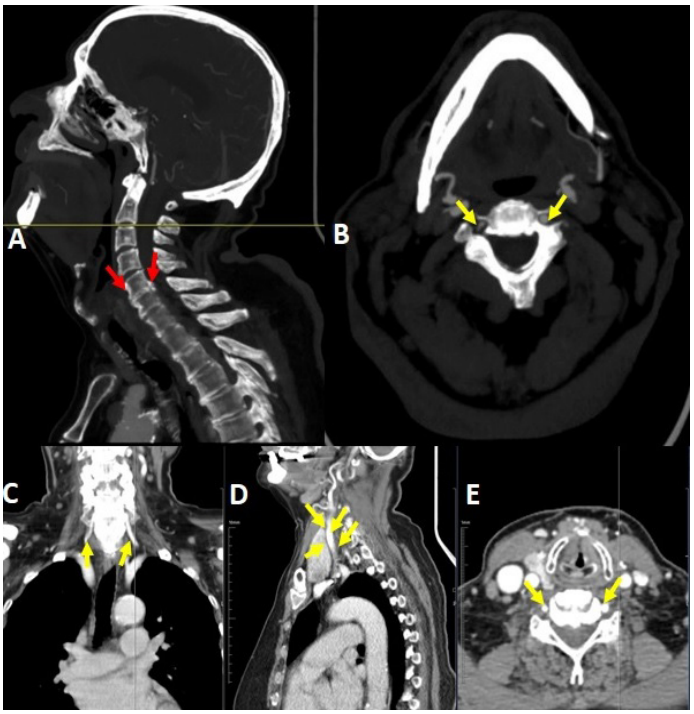

Figure 4. Cervical CTA images of two patients. The top images are of one patient and the bottom images are of another patient Above; left (**A**) is a cervical neck CTA image obtained by MPR in the sagittal plane and right (**B**) is a cross-sectional image in the axial plane. Arteries were evaluated in the vascular window on CTA; however, we chose an intermediate window setting to evaluate both bone degeneration and arteries in these two images. In A, the thin horizontal yellow line indicates the level of the slice on the right and the red arrows indicate osteophytic degeneration at the vertebral corners. In B, yellow arrows indicate the contrast-filled vertebral arteries within the transverse foramen. In the images below, MPR images in C. coronal and D. sagittal planes, and E. axial raw images in the vascular window, from left to right, with yellow arrows pointing to the vertebral arteries.

Similarly, osteodegenerative findings were found on cervical MRI examinations, and MRI had a higher image resolution in soft tissues (paraspinal ligaments and muscles) (Figure 5).

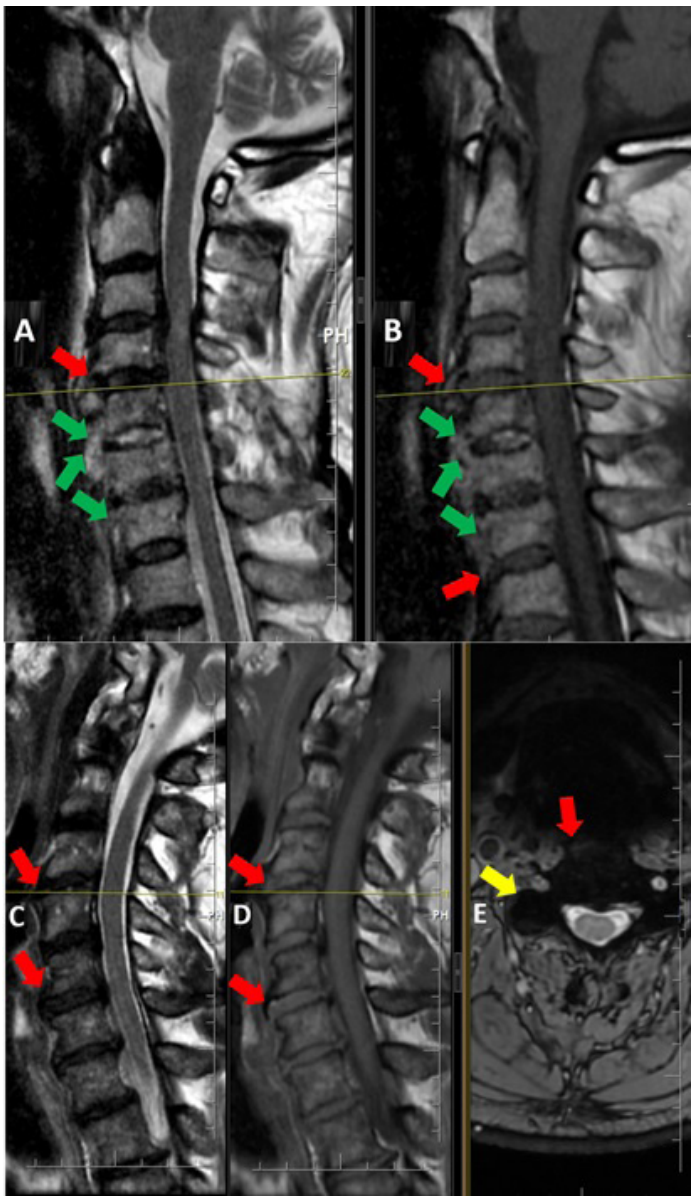

Figure 5. Cervical MRI images of the two patients. The top images are of one patient, and the bottom images are of another patient; the top two sagittal plane images (**A.** SE T2 and **B.** SE T1 sequences), red arrows indicate osteophytes, and green arrows indicate syndemophytes. On the basis of these features, this was a case of advanced degeneration. The lower image (**C.** SE sagittal plane T2, **D.** SE sagittal plane T1, and **E.** SE axial plane T2) is of a patient with moderate spondylosis; red arrows indicate osteophytes, and yellow arrow indicates degeneration in the right facet joint (SE: Spin echo).

All patients in the control group had conventional cervical CT and MRI and were evaluated on the basis of these examinations. CTA was not available for all patients in this group. In this group, there were no radiologic degeneration findings that could potentially cause significant compression of the transverse foramen and thus the vertebral arteries.

In the group of patients with moderate and severe degeneration, CTA examinations of all patients were available and the condition of the vertebral arteries was evaluated. Thus, by excluding patients with direct ischemia, such as critical stenosis and occlusion in the vertebral artery, we were able to exclude patients that should be excluded in order to be able to construct a study on the hypothesis of the negative effect of the dynamic process due to degeneration of vertebral artery hemodynamics, which is the main argument of the study.

Quantitative examination was performed using CT. On cranial CT examinations, HU units were measured from the neural parenchyma in the posterior fossae of patients with moderate and severe degeneration in terms of cervical spondylosis, from the widest location to include the cerebellum and brainstem. HU values were quantitatively measured in the control group. In HU measurements, the largest region was selected in the cerebellar hemispheres so that the white and gray matter of the hemisphere would be included in the measurement area, and the 4th ventricle and transverse sinuses would be spared from the measurement area, which was ensured to be of equal size in all patients for standardization; this area was approximately 7 cm^2. Similarly, the largest area that could be measured from the brain stem was measured from an area of 3 cm^2 in all patients in order to measure and standardize the largest area that could be measured. (Figures 6A).

Qualitative evaluations were performed using cranial CT and MRI. In addition to measuring density on CT, both CT and MRI were used to assess folium enlargement and volume loss, which represent cerebellar atrophy. Cerebellar atrophy was considered mild if the enlargement of the cerebellar folia was very mild and there was no significant volume loss, moderate if the cerebellar folia were more prominent and volume loss was also observed, and severe if there was a marked atrophic appearance (15). In addition, hypodense foci observed in the neural parenchymal area of the posterior fossa were considered. The appearance of these areas on MRI was also evaluated in terms of millimetic cerebrospinal fluid lacunes and increased signal in the periphery on T2 sequence images (especially fluid-attenuated inversion recovery [FLAIR]), which may be compatible with chronic lacunar infarction and/or gliosis, depending on the state of ischemia. Chronic lacunar infarcts were usually found in patients with moderate-to-severe chronic ischemia (Figure 6B). These were posterior circulation infarct (POCI) findings. Data were collected and categorized as described above and statistical analyses were performed.

Statistical analyses: All statistical analyses, subject to a significance threshold of $p<0.05$, were conducted using IBM SPSS for Windows (version 25.0; IBM Corp., NY, USA). Pearson, Spearman, or point-biserial correlation coefficients were calculated as appropriate to explore the relationships between the variables and HU on CT.

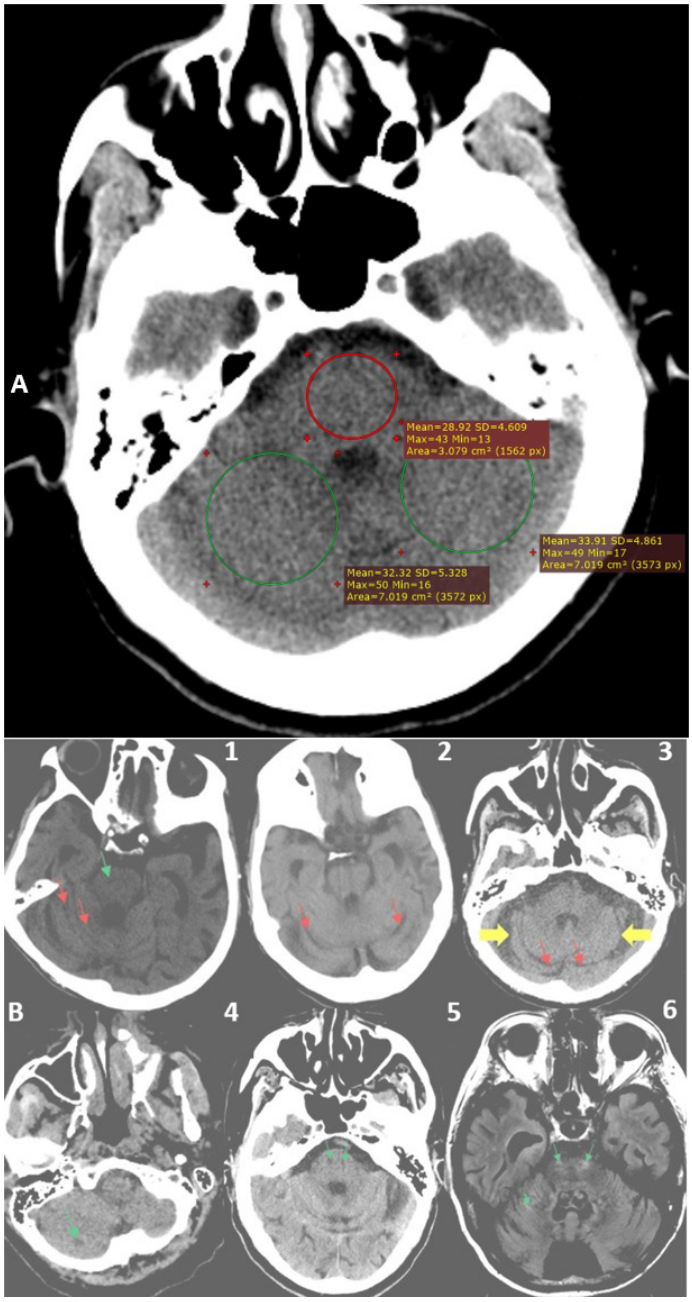

Figure 6. Examples of different cranial CT and MRI examinations in seven patients and HU measurement techniques in the posterior fossa on CT. Top image **A** shows density measurements in the brainstem and cerebellar hemispheres. In the lower **B** images, 1 shows a possible chronic ischemic focus in the brainstem (green arrow) in a patient with mild cerebellar atrophy (red arrows indicate marked reduction in folia). Figure 2 shows a case with more pronounced enlargement of cerebellar folia (red arrows indicate marked enlargement of the folia). Three showed an even more prominent enlargement of the cerebellar follicles (red arrows point to the prominent enlargement of the folia), and in this case, volume loss of the cerebellum was evident (yellow arrows point to the borders of the atrophic cerebellum with reduced volume). In image 4, foci of chronic ischemia in the right cerebellar hemisphere, and in image 5, foci in the brainstem are marked with green arrows. In image 6, foci of chronic lacunar infarction in the brainstem and the right middle cerebellar peduncle are marked with green arrows. These are the POCI findings.

RESULTS

Vertebral artery asymmetry was observed in 43 patients of the control group. The images in A and B in Figure 4 are from one such case. In 10 of these patients, asymmetry was prominent, the side with thin caliber was dominant, and the other side was hypoplastic (Table 2). However, the patients were asymptomatic. The HU values in these patients were within the normal range. From this perspective, unilateral hypoplasia of the vertebral artery does not cause an ischemic process under normal conditions. The site of vertebral artery hypoplasia has no effect on the ischemic processes. However, in patients with unilateral vertebral artery hypoplasia, atrophic changes, loss of density, and POCI findings in the neural parenchyma in the posterior fossa became statistically more prominent as the CS increased (p=0.02) (Table 2).

Table 2. Anatomical structure-variations of vertebral arteries and comparison of HU values of patients with and without unilateral hypoplasic vertebral artery

Control group		CS	
Symmetrical	**Dominant-hypoplasic**	**Symmetrical**	**Dominant-hypoplasic**
47	43	51	39
Severely hypoplasic		**Severely hypoplasic**	
10		8	
p=0.02			

CS: cervical spondylosis, p: Pearson correlation coefficient

Increased tissue ischemia is directly associated with aging. Therefore, it is expected that the CT density of the tissue in the cerebral parenchyma will decrease after a certain point with increasing age. In our control group, the highest HU was 26 and the lowest HU was 24. There was no statistically significant decrease in the HU values of the neural parenchyma of the posterior fossa with increasing age (p=0.09) (Table 3).

Table 3. Statistical correlation between the characteristics of the patients and HU values

Control group	
Age	**HU**
p=0.09	
CS	
Age	**HU**
p=0.07	
CS severity	**HU**
p=0.03	
CS severity	**Cerebellar atrophy and POCI**
p=0.04	

CS: cervical spondylosis, p: Pearson correlation coefficient

Among the 90 patients with CS findings in the pathological sample, 39 had asymmetry in the vertebral arteries. The images in C, D, and E in Figure 4 are from one such case. In eight of these patients, the asymmetry was quite prominent and the artery contralateral to the dominant side was highly hypoplastic with an extremely thin caliber (Table 2).

In our pathological sample group, which constituted the main population of the study, the highest HU value was 23 and the lowest HU value was 17. There was no significant correlation between HU values of the neural parenchyma of the posterior fossa and increasing age (p=0.07) (Table 3).

The cumulative mean HU values in the cerebellum and brainstem decreased significantly as the severity of degeneration of the cervical vertebral column increased (p=0.03). Similarly, as the degree of CS progressed, the frequency of cerebellar atrophy and POCI findings increased significantly (p=0.04) (Table 3).

Both quantitative HU values measured on CT and qualitative findings of cerebellar atrophy and POCI on CT and MRI were statistically compared between the control group and patients with moderate-to-advanced degeneration. As a result of this analysis, both HU values were lower (p=0.02) and qualitative findings were more pronounced ((p=0.04) in the study population (Table 4).

Table 4. Statistical comparison of the control group and patients with moderate and advanced degeneration in terms of HU and POCI

Control group	CS
HU	p=0.02
Cerebellar atrophy and POCI	p=0.04

CS: cervical spondylosis, p: Pearson correlation coefficient

DISCUSSION

The main idea of our study is based on the idea that hemodynamic disturbances may occur dynamically during neck movements in daily life. In cases of mild CS, there is usually no possibility of external compression of the vertebral arteries by osteophytes. In patients with moderate degeneration, vertebral artery compression may be observed due to osteophytes at one or more levels and/or degeneration in the unvertebral joints and facet arthrosis. In cases of severe degeneration, there are multiple levels of osteophyte-complicated joint and disc degeneration, ligament thickening and calcification, and even syndesmophytes, and usually bilateral foramen transversarium stenosis and possible vertebral artery stenosis secondary to this. These stenoses may not be detected on a cross-sectional image at first glance.

Spinal degeneration is classified according to narrowing of the spinal canal and compression of the spinal cord, especially in the cervical region. As we did not evaluate the patients from this point of view, we made a classification according to the compressibility of the vertebral arteries secondary to degeneration in the dynamic process by determining the framework, albeit qualitatively. Our study was based on the possibility that hemodynamics may be disrupted by neck movements, even in the absence of significant static stenosis in the vertebral arteries. The vertebral column has an intricate anatomical relationship with the vertebrae and paravertebral tissues in a compact space, particularly in the spinal region (15).

CS is a clinical condition that increases in severity with age. However, this does not always occur with age. In some patients, bone structure, metabolic processes, and lifestyle predispose them to degeneration. Moderate or advanced degeneration is observed in middle-aged patients, whereas in others, mild degeneration may be observed even if they are quite old (16,17). Some of our patients had moderate degeneration findings despite being in the middle-aged group and mild degeneration findings despite being in the advanced age group.

Vertebral arteries are arterial vascular structures that are vulnerable to atherosclerosis because of their relatively narrow lumen diameters, emergence from the subclavian artery as a steep branch, sharp kinks in their course, tortuosity in many locations, and long course (18,19). If external luminal compression secondary to cervical degeneration is added to the critical stenosis, a decrease in perfusion in the posterior circulation area is inevitable. Particularly in the elderly population, the incidence and severity of atherosclerosis and CS increase, and the deterioration of hemodynamics creates a predisposition to this condition at later ages (20,21).

In our study, we investigated whether the hemodynamics of the posterior circulation, that is, the vertebrobasilar system, are impaired due to movement in the background of CS. There is insufficient data on this subject in the literature. Studies in the literature generally aim to investigate acute ischemic processes related to static stenosis in the vertebrobasilar system or chronic ischemic changes secondary to stenosis. Therefore, in the literature, acute vertebrobasilar insufficiency developed in conditions such as trauma, dissection, and chronic ischemic processes due to stenoses caused by atherosclerotic changes in the vertebral lumens or stenoses developed due to external compression of the lumen predominate (22-28). In our study, we attempted to detect ischemic processes caused by vertebrobasilar insufficiency secondary to dynamic and frequent compression of the vertebral arteries due to neck movements, although no critical stenosis was observed on static examination.

Although acute disturbances in hemodynamics are tolerable, damaging effects may occur when chronic and persistent abnormalities develop, even in small amounts (29,30).

According to the literature, the HU value of gray matter in normal cerebral parenchyma is approximately 35 and that of white matter is approximately 25 (31). Based on this information, it would not be incorrect to express a mean value of 30 HU. In our measurements, we aimed to examine the cerebellar hemisphere and brainstem in a manner that covers both components at nearly equal rates. The HU values of our patients in the control group ranged from to 24-36 with a mean of 27, which is approximately in agreement with the data in the literature. In the group that constituted the main population of our study, we found a minimum HU of 17 and maximum HU of 23. The cumulative decrease in these values was probably

secondary to the ischemic processes caused by CS, as determined statistically.

Study Limitations

One of our most important limitations is that the patients were not analyzed in terms of hypertension, diabetes, and cardiovascular disease status. While classifying the cases in terms of spondylosis, the grouping of some cases was not completely clear, and they were included in whichever group was predominant. Another limitation is the difficulty of measuring HU on CT examination; in other words, the value obtained may not be reliable. Artifacts caused by the calvarial bones in the posterior fossa may cause this situation. Another limitation is the possibility that fluctuations in blood pressure may also contribute to hemodynamic disturbances. The small number of cases is also a limitation.

In our study, when the qualitative and quantitative findings of the control group and the group considered pathological were compared statistically, the results supporting chronic ischemia were found at a higher rate in cases with moderate and advanced CS, in terms of both parameters.

CONCLUSION

Although cervical vertebral column degeneration is not acutely symptomatic, it can cause long-term ischemia in the neural parenchyma in this region by adversely affecting perfusion in the posterior system, with recurrent micro-hemodynamic disturbances through the vertebral arteries.

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Conflict of interest: *The authors have no conflicts of interest to declare.*

Ethical approval: *The approval and permission of the Academic Board and Ethics Committee of Nişantaşı University (date: 14.08.2023, decision No: 13).*

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