

Radial Visualization of the Foramen Arcuale Atlantis

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Abstract Introduction. The posterior parts of the brain are nourished by the vertebral arteries passing in the canal of the transverse processes of the cervical vertebrae. Blood circulation in the vertebrobasilar region often can be impaired and the reason for this is mainly the influence of the bone structures of the cervical spine (spondylogenic factor). The consequence of such changes can be caused a slight decrease in cerebral circulation to ischemic complications in the vascular bed (vertebrobasilar insufficiency). **Objective of the study:** to assess the effect of Kimmerle's anomaly on blood circulation in the vertebrobasilar zone. **Materials and methods.** Of the 381 patients examined from January 2020 to March 2021, 62 were diagnosed with a Kimmerle anomaly by cervical spine X-ray. All participants in the study underwent computed tomography (CT) of the brain with the capture of the upper cervical spine, ultrasound Doppler and transcranial Doppler (TCD) of the vertebral arteries (PA). The exclusion criteria from the examination were patients with tumors, cerebral hemorrhages, with manifestations of severe arterial hypertension. Statistical data were obtained using "Statistic 6.0" software. **Results.** Studies of the variant of the development of the first cervical vertebra with the presence of a bony bridge have shown that Kimmerle's anomaly can occur in all age groups. Most often, bilateral Kimmerle anomaly was detected, which, according to TCD, affects the blood flow. In the unilateral variant, the anomaly was observed mainly on the left side. **Conclusions.** The frequency of detection of Ponticulus posticus was within 16.3% of cases, that is, it occurs in every 5-6 people and is common in all age groups, with a prevalence in young and middle age. It was found that the main structural change in the cerebral vascular bed, according to ultrasound diagnostics, is a change in the straightness of the vertebral arteries in the transverse processes of the cervical spine, including the atlas. **Recommendations.** For the patients with various complaints such as pain in the cervical region, headache, dizziness, flashing of flies in front of the eyes, it is recommended to conduct an X-ray of the cervical spine in 2 projections or at least in the lateral one. It is necessary to perform CT to clarify the state of the morphology of the vertebrae and their possible effect on the blood flow in the vertebral arteries. In patients with diagnosed Kimmerle's anomaly using ultrasound duplex sonography and transcranial Doppler sonography. It is necessary to assess the blood flow in the V3 and V4 segments of the vertebral arteries.

Keywords Vertebral artery, Vertebrobasilar insufficiency, Computed tomography, Transcranial Doppler ultrasonography, Kimmerle's anomaly

1. Introduction

Considering that increase in the percentage of cerebral vascular lesions in the structure of the causes of morbidity and mortality in the population, the problem of reducing blood flow in the craniovertebral zone occupies a special place. The pathology of the cerebral vessels leading to a slowdown in cerebral circulation in the vessels of the vertebral and basilar zones is diagnosed in 20-30% of people and occupies one of the leading positions in the overall structure of morbidity and disability standing out in the group of people of working age [1-3,6-8,15,23]. According to scientific works of recent years, the rates of morbidity and mortality in vascular pathologies of the brain are invariably

high [6,7,15,23]. According to the observations of researchers, bone abnormalities, as well as arterial abnormalities, or a combination of both, can cause a decrease in cerebral blood flow [6,15,24]. There is evidence that one of the main reasons leading to changes in the straightness of the blood flow of the cerebral arteries is a change in the course of the VA [4,9,10] in the canal of the transverse processes of the cervical vertebrae of the atlas (C1). Based on scientific data in recent years, high importance is attached to the presence of an arcuate foramen of the first cervical vertebra. Arcuate foramen of atlas is an ossification of the oblique atlanto-occipital ligament superior to the vertebral artery groove of the atlas. The vertebral artery, which passes under these bony projections, can be compressed along with the suboccipital nerve causing a variety of symptoms. According to some resources this change in C1 was diagnosed in 37-80% of the surveyed (Fig. 1). This change in atlas is found in literary sources under the names: arched foramen of the atlas, superior posterior articular foramen,

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Received: Nov. 25, 2021; Accepted: Dec. 3, 2021; Published: Dec. 15, 2021

Published online at <http://journal.sapub.org/ajmms>

bony bridge or arcuate foramen of the first cervical vertebra, but is more often referred to as Kimmerle's anomaly (KA).

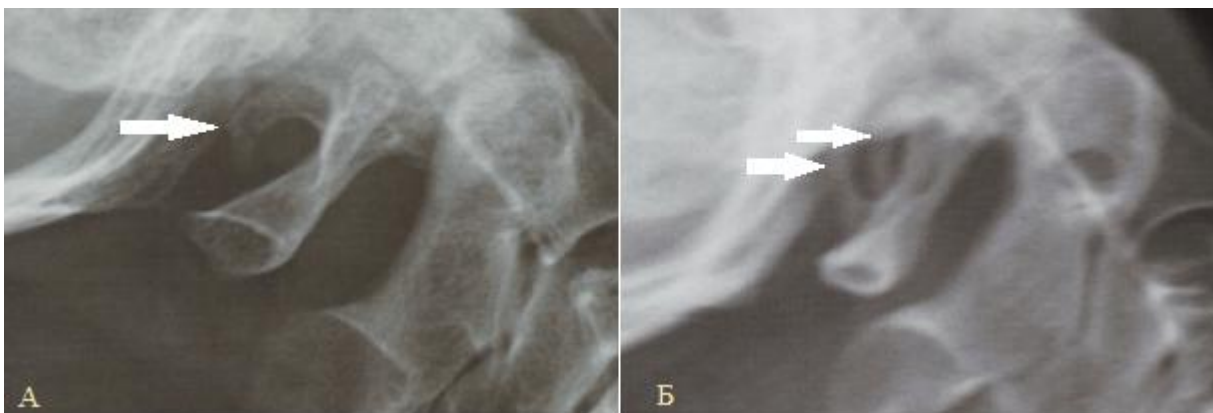


Figure 1. Radiography of the vertebrobasilar zone, lateral projection A - unilateral posterior incomplete bone bridge of the first cervical vertebra (Kimmerle anomaly) B - bilateral posterior complete bone bridge of the first cervical vertebra

Some resources admit the possibility that KA is a developmental option that does not deserve special attention but there are isolated clinical observations mentioning the development of focal ischemia of the brain stem in the presence of a C1 bone bridge [6,7,15,16,23]. Changes in the cervical vertebrae affect the mobility of the PA at the site of AA formation and can lead to a decrease in the blood flow of the vertebrobasilar zone [11-14,19]. Stretching during movement or manipulation by the chiropractor as well as rotation and bending of the cervical spine in the foramen can cause excessive external pressure on the V3 segment of the vertebral artery with dynamic stenosis and changes in normal blood flow. This observation has been associated with posterior circulation stroke in patients with Kimmerle's anomaly [6,7,15,16]. The presence of this pathology may also play a causal role in the genesis of vertebral artery dissection (dissection) [17] and this has been described as a predisposing factor in sudden infant death syndrome [6,16,22,23].

As a result of a slowdown in blood flow in the craniovertebral zone cerebral and spinal cord infarctions can develop. A significant part of this is ischemic stroke while cerebral ischemic stroke accounts for 7-11%, and spinal cord - 1-2% of all strokes [6,12,13].

Comparison of the data, obtained by several scientists, shows that a considerable share of the consequences of circulatory disorders entails a change in blood circulation in the vertebrobasilar zone and in the vertebral arteries, in particular. It is known for certain that PA, which supplies the vertebrobasilar zone and the posterior parts of the brain, penetrates into the skull through the canal of the transverse processes of the cervical vertebrae. Based on this, pathologies of the cervical spine are often the cause of impaired blood flow in the vessels of the craniovertebral zone in any age group [3,4,9,10].

During diagnosing by angiography and after intraoperative verification was found that the C1 bone bridge manifests itself as vertebrobasilar insufficiency only

in 5.5% of cases, provided there is a cicatricial stranglehold around the VA [7]. That means the term "variant" can be part of the Atlantean variety, which does not lead to pathological consequences [4]. Basically KA does not cause vertebrobasilar ischemia and has an asymptomatic course [7]. The main factors in the development of clinical symptoms in patients with Kimmerle's anomaly are: extravasal compression of the VA, prolonged trauma to the adventitia of the vessel, as well as irritation of the perivascular plexuses and branches of the occipital nerve. [7,18,23].

The arcuate foramen is an important anatomical variant of the atlas that surrounds the vertebral artery and periarterial structures and it can be considered another example of how minor abnormalities of the atlantooccipital region can lead to a pathophysiological state of clinical significance [19,22].

2. Purpose of the Study

To assess the effect of Kimmerle's anomaly on blood circulation in the vertebrobasilar zone.

3. Materials and Methods

Was carried out the complex radiation diagnostics of the craniovertebral region of patients with verified Kimmerle's anomaly. We analyzed the data of X-ray examination of patients who complained for headaches and cervicgia from January 2020 to March 2021. Kimmerle's anomaly was detected In 62 out of 381 examined and computed tomography (CT) of the brain was performed with the capture of the upper cervical spine for these 62 patients. The examination was carried out on a GE-Optima 520 apparatus with 16 rows of slices (manufactured in the USA). CT scan parameters: tube current - 249 mA for a CT head, voltage - 120 kV, tube rotation speed - 1.0 s, pitch - 0.85, slice

thickness 1.25 mm. The radiation exposure at CT was 2 mSv. Ultrasound duplex sonography of the V3 vertebral artery was performed using ESoate Mylab class C (linear transducer - 5-7.5 MHz, convex transducer - 2-5 MHz). Transcranial Doppler sonography was performed using the "EDAN instruments" version 1.2 system using a phased transducer with a frequency range of 3-7 MHz. The exclusion criteria from the examination were patients with tumors, cerebral hemorrhages, with manifestations of severe arterial hypertension. Statistical data were obtained using "Statistic 6.0" software.

The study was carried out on the basis of the medical clinic of the Samarkand State Medical Institute and agreed with the management. All patients consented to this examination. Bioethics committee conclusion (ClinicalTrials.gov): ID NCT04562259.

4. Results

Clinical complaints in 62 examined patients manifested themselves in the form of dizziness, various types of headache, mainly localized in the occipital region, nausea or flashing of flies in front of the eyes, in the rest - only cervicalgia. The pain was paroxysmal. The examinees associated the appearance of pain and discomfort mainly with the "uncomfortable" position of the head or neck during sleep, a sudden movement, and a change in position. Palpation reveals tension in the occipital muscles. The vertebrobasilar region is a complex department of the anatomical functions of the muscular frame and the location

of the vessels.

A diagnostic examination was carried out: 11 patients under the age of 30 years, 15 patients aged 31 to 40 years, 18 patients aged 41 to 50 years, 13 - from 51 to 60 years old and 5 patients over 61 years old. The age period of the patients ranged from 18 to 85 years. The average age in the male part of the patients was 47.3 years, in the female - 54.1 years, while the Kimmerle anomaly was almost equally noted in both men and women.

When evaluating computed tomograms of the brain of patients with diagnosed Kimmerle's anomaly 41.9% of cases showed signs of vascular encephalopathy in 19.4% of cases signs of cerebellar atrophy and in 9.7% of cases single cysts. In the prevailing percentage of patients with Kimmerle's anomaly examined by us the posterior arch of the atlas was visualized on the screen as a high-density band on computed tomography, over which an annular hypodense zone was determined, bordered by a partially or completely closed hyperdense ring - a bone "bridge" (ponticulus posticus) (Fig. 2).

The results of our studies showed that in 48 patients (77.4%) with diagnosed Kimmerle's anomaly, there is a bilateral location of the arcuate foramen of the first cervical vertebra. In 14 cases, the Kimmerle anomaly was one-sided, and almost all of them (85.7%) were located on the left.

Ponticulus posticus, located on the right, was closed in 75.8% (complete Kimmerle anomaly) and open in 27.4% (incomplete Kimmerle anomaly). The arcuate foramen of the first cervical vertebra above the left arch was closed in 47 cases and open in 13 cases.



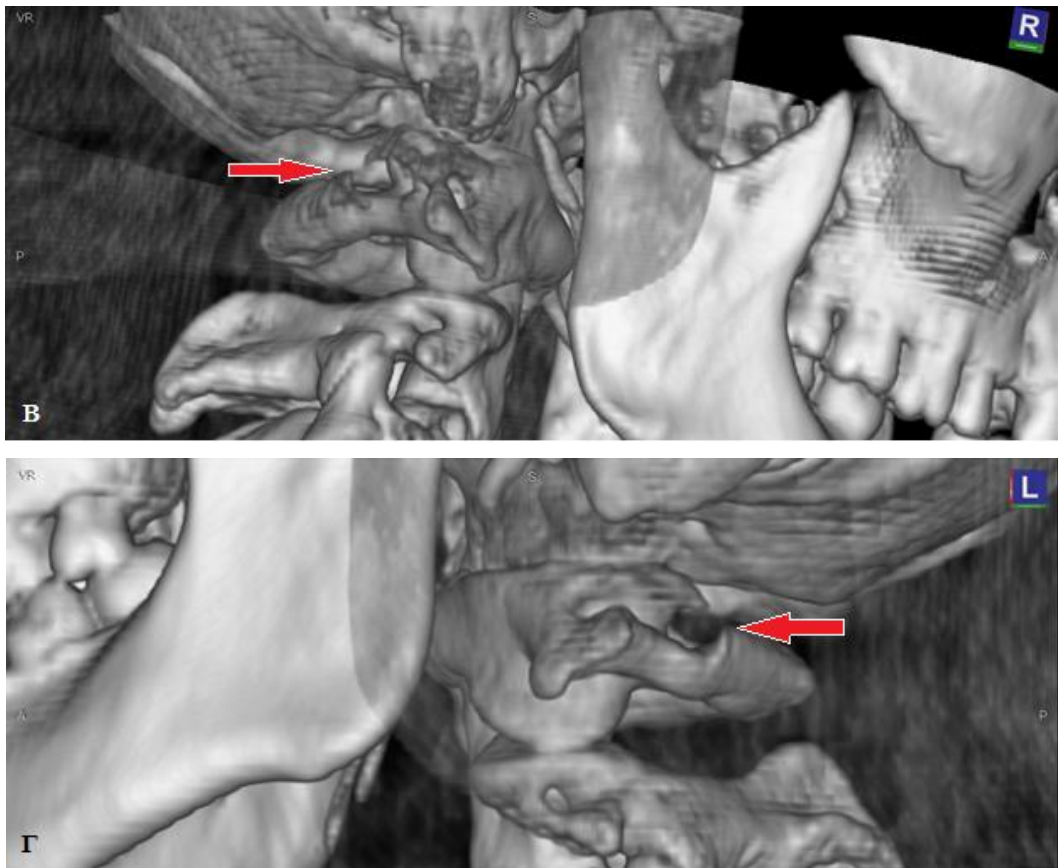


Figure 2. Computed tomography with 3D reconstruction. Craniocervical articulation: A) rear complete Kimmerle ring on the right, B) posterior complete ring C1 on the left, C) posterior incomplete ring C1 on the right, D) posterior incomplete ring C1 on the left (indicated by arrows)

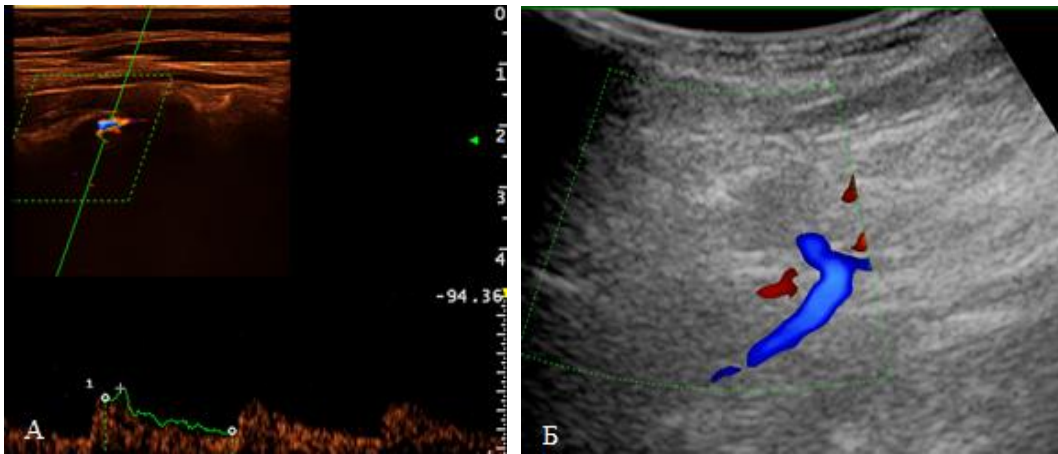


Figure 3. Doppler ultrasonography of the vertebral arteries Craniocervical department: A - visualization using a linear sensor, Б - visualization using a cavity sensor

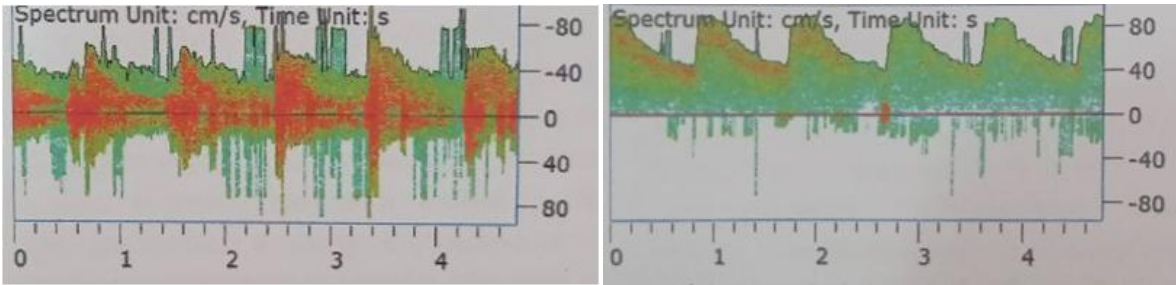


Figure 4. Transcranial Doppler ultrasonography of the vertebral artery. Vertebrobasilar department

Measurements of the parameters of the vaulted opening by tomography showed that the anteroposterior dimension during measurements was from 2.9 to 11.3 mm, the vertical dimension of the opening was from 2.8 to 6.8 mm. The thickness of the bone bridge forming the roof of the hole varied from 0.6 to 3.5 mm.

To clarify the cause of the above neurological complaints and establish a connection with Kimmerle's anomaly we performed a Doppler examination of the vessels of the cervical spine. During performing Doppler ultrasonography of the V3 segment of the vertebral arteries, based on the experience of scientists [1], we faced a number of difficulties: a short neck, large thickness of soft tissues, a complex direction of the vertebral artery. As a result, visualization of the V3 segment was obtained only in 3 out of 62 patients which did not provide diagnostically significant information and is consistent with the data of some authors [14] (Fig. 3).

At the next stage, based on the standard indicators of blood flow in the vertebral arteries according to Zwibel [21], we examined the patients by ultrasound transcranial Doppler sonography. This examination revealed a decrease in the velocity indicators of blood flow in the 4th segment of the vertebral arteries, covered by a closed bone ring with Kimmerle's anomaly.

In patients with unilateral open variant of Kimmerle's anomaly up to 50 years, hemodynamically significant changes in blood flow velocity were not observed: in the V3 segment of the vertebral artery the average blood flow velocity was 35.7 ± 6 cm / s, in the V4 segment - 38.2 ± 6 , 2 cm / s. In opposite to these data in the remaining groups in patients diagnosed with an open variant of Kimmerle's anomaly we noted a decrease in blood flow within the lower limit of the normative criteria: the average blood flow velocity in the V3 segment of the vertebral artery was 27.2 ± 5.2 cm / s, in the V4 segment - 28.3 ± 5.3 cm / s. In patients with a closed form of Kimmerle's anomaly in all age groups hemodynamically significant changes in blood flow on this side were noted although it did not always lead to neurological symptoms: in the V3 segment - 20.1 ± 4.5 cm / s, in the V4 segment - 21.4 ± 4.6 cm / s, which was probably compensated by the opposite vertebral artery where the blood flow velocities were within the normal range (Fig. 4). Only the presence of a closed bone ring C1 on both sides led to a slowdown in blood flow through the basilar artery (26.5 ± 5.1 cm / s), which is possibly evidence of the severity of neurological complaints. The incidence of Kimmerle's anomaly in the patients examined by us was 16.3%.

Peripheral hemodynamic resistance is inversely proportional to the size of the vessel diameter. Bone bridge C1 like other extravasal causes of PA compression, atherosclerotic and septal stenosis of PA can cause a decrease in blood flow in the vessels of the vertebrobasilar zone.

Based on this there is a decrease in blood flow in the PA on the side of the diagnosed bone bridge C1. Kimmerle's anomaly is one of the main risk factors for the early development of cerebrovascular disorders and contributes to

disorders of arterial hemodynamics which is consistent with literature data [17,20,21].

5. Conclusions

Summing up we can say that the relevance of studying the effect of craniovertebral insufficiency on the occurrence of blood flow disturbances in the vertebrobasilar vascular bed, the search for reliable and, at the same time, available methods for identifying, optimizing therapeutic methods for this pathology require appropriate studies. The main structural change in the cerebral vascular bed, according to ultrasound diagnostics, is a change in the straightness of the vertebral arteries in the transverse processes of the cervical spine.

In our study, the frequency of the vaulted opening is close to the average occurrence of this feature (16.7%) [4,21], however, according to some authors, ponticulus posticus is diagnosed from 8.3% [6] to 12% of the occurrence. Interestingly, in some studies, these changes were found in one third of the examined and even from 37 to 80% of patients [7,17]. In the studies of individual authors, it is said that incomplete forms with many different variations are often encountered, as a result of which there is no consistent classification in the literature [3,5] and they may not be taken into account.

Nowadays the ability of computed and magnetic resonance imaging to obtain detailed anatomical information about the structure of the spine and craniovertebral region provides a unique opportunity to renew attention to this complex area of the skeleton [24]. However, for assessing the morphology of bones and their trabecular structure including the bone bridge of the atlas, CT has better visualization than MRI.

Statistics say that the incidence of the Kimmerle anomaly is 16-20% and this is certainly a frequent change in C1. This change correlates with the types of pathological abnormalities of the vascular bed of the brain and the main arteries of the head. A review of the literature once again proves the importance of vascular changes in the onset of cranialgia and requires special treatment and prevention tactics. It must be admitted that today doctors do not think, and some do not even know about the possibility of the existence of this pathology and for months and sometimes for years they carry out symptomatic therapy not suspecting that the Kimmerle anomaly can be confirmed or excluded by routine methods.

In order to predict the impact of the presence of ponticulus posticus several questions need to be resolved:

- to establish the ratio of the diameters of the vessels to each other and to the diameter of the C1 bone bridge,
- determine full or incomplete arcuate foramen,
- unilateral or bilateral pathology,
- options for the structure of the great vessels in each individual case.

The combination of these data can predict possible causal factors that can cause a decrease in cerebral blood flow, which in turn leads to early disability and loss of working capacity.

6. Recommendations

Patients with complaints of pain in the cervical region, headache, mainly in the occipital region, dizziness, flashing of flies in front of the eyes and if a certain pathology is not identified that causes these symptoms we recommend performing an X-ray of the cervical spine in frontal and lateral projections or although would be in the side.

If Kimmerle's anomaly is found, at the next stage, the study must be supplemented with CT to clarify the state of the morphology of the vertebrae and their possible effect on blood flow in the vertebral arteries.

It is necessary to assess the blood flow in the V3 and V4 segments of the vertebral arteries by using ultrasound duplex sonography and transcranial Doppler sonography.

The results of this study emphasize the importance of the role of the spondylogenic factor, which can cause or contribute to the development of circulatory disorders in the vertebrobasilar zone. Arterial and venous discirculation with prophylactic detection by radiation research methods, by means of CT and transcranial Doppler ultrasonography, has a positive prognosis for the therapy of cerebrovascular changes in patients with KA.

Funding source and conflict of interest. This article does not have financial support for the study and conflicts of interest of the authors, which must be reported.

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