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PATHOLOGICAL CHANGES OF THE CERVICAL SPINE IN CHILDREN WITH CERVICAL PAIN SYNDROME

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Background. Interpretation of cervical pain syndrome in children is complicated, resulting in delayed diagnosis of developmental juvenile osteochondrosis. Thus, updating the diagnostic methods of this pathology is particularly important.
Aim. To improve methods of cervical spine diagnostics in children with cervical pain syndrome at the base of vertebral and basilar arteries using duplex ultrasound.
Material and methods. The study cohort included 148 pediatric patients aged 4–18 years who were divided into two groups: a treatment group of 108 children with cervical pain syndrome and a control group of 40 healthy children. Clinical, radiological (ultrasound, X-ray, and MRI), and statistical methods were used for comparisons.
Results. Duplex ultrasound of 108 patients revealed pathological changes of qualitative and quantitative features of C- or S-shaped, corner bend, mesh, excessive, and wave-shaped tortuosity deformities, as well as a reduction or expanse in diameter of one or two of the spinal arteries (SAs). The absence of an influence of osseous cervical spine structures on SAs was considered a sign of congenital genesis of SA deformity, while segmental instability of C_2-C_3 and/or C_3-C_4, atlanto-axial subluxation, and a Kimmerle anomaly were considered signs of extravascular compression of SAs. Regardless of the deformity genesis, blood flow was deficit in the vertebral basilar basin because of local hemodynamic disorders at the site of the deformity, particularly in older children. MRI revealed signs of intervertebral disc hypohydration at C_2-C_3 and/or C_3-C_4.
Conclusion. Pathological changes in SAs of both congenital and acquired genesis resulted in hemodynamic disorders in the vertebral basilar basin in children with cervical pain syndrome, particularly older children.

Keywords: children, cervical pain syndrome, cervical spine.

ПАТОЛОГИЧЕСКИЕ ИЗМЕНЕНИЯ В ШЕЙНОМ ОТДЕЛЕ ПОЗВОНОЧНИКА У ДЕТЕЙ С ЦЕРВИКАЛЬНЫМ БОЛЕВЫМ СИНДРОМОМ

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Введение. Сложность интерпретации цервикального болевого синдрома у детей приводит к поздней диагностике развивающегося юношеского остеохондроза, в связи с чем особую значимость приобретает использование современных методов диагностики данной патологии.
Цель исследования: совершенствование диагностики патологии шейного отдела позвоночника у детей с цервикальным болевым синдромом на основе комплекса инструментальных исследований, включающего дуплексное исследование позвоночных и основной артерий.
Материал и методы. Обследовано 148 пациентов в возрасте от 4 до 18 лет, в том числе 108 детей с цервикальным болевым синдромом (основная группа), 40 здоровых детей (группа сравнения). Использовали клиниче-

ские, лучевые (рентгенологический, ультразвуковой, МРТ (магнитно-резонансную томографию)), статистические методы исследования.

Результаты. При дуплексном исследовании позвоночных артерий (ПА) у 108 пациентов были выявлены патологические изменения качественных и количественных характеристик одной или двух артерий по типу С-, S-образных деформаций, деформаций в виде «углового» изгиба, «петли», «избыточной», «волнообразной» извитости, а также уменьшение или увеличение диаметра ПА. О врожденном генезе деформации ПА свидетельствовало отсутствие воздействия на нее костных структур шейного отдела позвоночника, а наличие нестабильности сегментов C_2-C_3, C_3-C_4, ротационного подвывиха атланта, аномалии Киммерле — об экстравазальной компрессии ПА. Независимо от генеза деформации отмечалось нарушение кровотока в вертебробазилярном бассейне вследствие локальных гемодинамических расстройств в области деформаций, особенно у детей старшего возраста. При МРТ-исследовании были выявлены признаки гипогидратации межпозвонковых дисков заинтересованных сегментов.

Заключение. У детей с цервикальным болевым синдромом отмечаются патологические изменения ПА приобретенного или врожденного генеза, приводящие к расстройству гемодинамики в вертебробазилярном бассейне.

Ключевые слова: дети, цервикальный болевой синдром, шейный отдел позвоночника.

Introduction

The prevalence of cervical pain in children ranges from 5 to 72%, and its rate of occurrence tends to increase [1, 2]. In most cases, the complaints of discomfort in the neck, headaches, and dizziness are considered by neurologists and pediatricians as the manifestation of vegetovascular dystonia. However, these symptoms can be caused by functional and organic changes in the bone and soft-tissue structures of the cervical spine [3–6]. The increased incidence of cervical pain in children and the simultaneous complexity of this interpretation lead to late diagnosis of the developing juvenile osteochondrosis, which decreases the patient's quality of life. In this regard, the use of modern research methods to improve the diagnosis of cervical spine diseases in children with cervical pain syndrome acquires special significance [7–11].

The **aim** of this study was to increase the accuracy of diagnosis of cervical spine diseases in children with cervical pain syndrome, including duplex ultrasound of the vertebral and basilar arteries.

Material and methods

The study cohort included 148 pediatric patients aged 4–18 years, of which 108 had cervical pain syndrome (study group) and 40 were healthy patients of the same age (control group). The study cohort consisted of 59 boys and 49 girls. Written informed consent for participation in the study was voluntarily provided by patients or their parents. The study was approved by the local ethics committee of the Federal State Budgetary Institution Saratov Research Institute of Traumatology and Orthopedics of the Russian Federation Ministry of Health (Protocol No. 5 dated 10/29/2009).

During the study the clinical, radiation (ultrasound, X-ray, magnetic resonance tomography), and the statistical research methods were used.

Ultrasonography was performed on the multi-function, high-class ultrasound scanner Technos MPX manufactured by ISAOTE (Italy). The qualitative (diameter, vascular geometry, and the level of entry into the bony canal) and quantitative characteristics of the vertebral artery blood flow were determined (*Vps*: peak systolic velocity of blood flow; *Ved*: end diastolic velocity of blood flow; and *RI*, the resistance index). The hemodynamic status of the vertebral artery (VA) and basilar artery (BA) was represented by the peak systolic velocity of blood flow. X-ray of the cervical spine in the anteroposterior and lateral views was performed using a digital X-ray machine manufactured by Apelem (France). According to the results of duplex ultrasound of the cervical vessels, the necessity for transoral (through the open mouth) X-ray of the cervical spine and functional tests of maximum flexion and extension of the neck was determined. Magnetic resonance imaging (MRI) of the cervical spine was performed to determine the extent of damage to the intervertebral discs when unstable vertebral-motor segments on functional X-ray images were detected. This was performed using a MRI scanner of the open-type Aperto manufactured by Hitachi (Japan), with the magnetic field strength of 0.4 T.

The numerical results were processed using parametric variation statistics with significance

determined by Student's t tests. The results were considered significant at $p < 0.05$.

Results and discussion

All patients had pain in the neck, headache, and dizziness. During examination, we considered the presence of the natural bend of the head, shoulder girdle asymmetry, contouring, and tension of the shoulder girdle and neck muscles, and painfulness of the paravertebral points and spines of the cervical vertebrae.

Duplex ultrasound of VA was performed in 108 patients with cervical pain. In 94 (87%) of the 108 patients, pathological changes of the qualitative and quantitative characteristics of one or two VA were found, which were used to divide all patients into two groups. In the remaining 14 (13%) patients, the ultrasound VA figures were within normal limits. Considering the localization of pathological changes of the blood vessels, subgroups were formed: *a,* V_1 segment; *b,* V_2 segment; *c,* V_3 segment; *d,* V_1–V_4 segments; and *e,* combination of different segments (Table 1). Subgroup *e* was excluded from the analysis due to the diversity of localization variants. In the bilateral process, the segmental levels of lesion localization were distributed to the respective subgroups for statistical analysis.

For a duplex study of the VA and BA in the patients of the subgroup *a,* there was a statistically significant decrease in *Vps* in segment V_1 to 0.28 ± 0.10 m/s ($p < 0.003$); this increased in segment V_2 to 0.69 ± 0.21 m/s ($p < 0.05$). The rest of the blood flow velocity indices in segments V_3 and V_4 of the VA and BA did not differ from the control group (Table 2).

During the X-ray examination of subgroup *a*, the flattening of the cervical spine was detected predominantly. The examination results revealed that in subgroup *a* pediatric patients with S- and C-shaped VA deformities in segment V_1 (subgroup *a*), the said segment was not adjacent to the bone structures of the corresponding lower cervical spine (the vertebral level C_6–C_7), indicating a congenital genesis of the VA deformities (Fig. 1 *a, b*).

Segment V_2 is localized in the bony canal formed

Table 1

The distribution of pediatric patients by subgroups, depending on the level of unilateral or bilateral lesions of the vertebral arteries and the total number of the affected segments

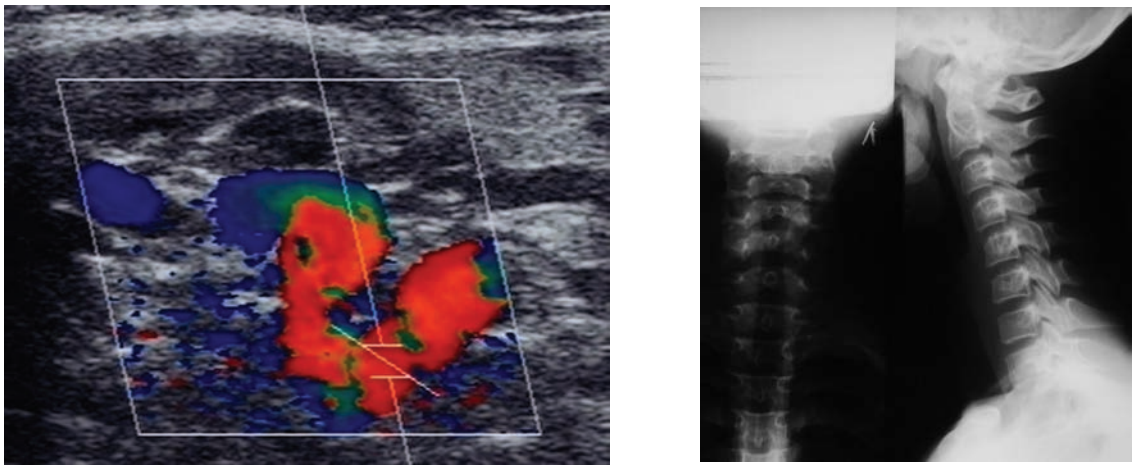
Subgroups	The groups of patients aged 4–18 (n = 94)		The number of affected segments based on pathologic changes in the collateral vertebral artery
	With unilateral lesion of the vertebral arteries	With bilateral lesion of the vertebral arteries	
a	3 (3,2 %)	3 (3,2 %)	9
b	36 (38,3 %)	16 (17,0 %)	68
c	11(11,7 %)	5 (5,3 %)	21
d	–	5 (5,3 %)	10
e	6 (6,4 %)	9 (9,6 %)	–
Total	56 (59,6 %)	38 (40,4 %)	–

Table 2

Blood flow velocity indices of the vertebral arteries and basilar artery in children with C- and S-shaped deformities of the V_1 segment of the vertebral artery (n = 9; M ± m)

Blood flow velocity	Groups	Segment V_1	Segment V_2	Segment V_3	Segment V_4	Basilar artery
Vps, m/s	control	0,38 ± 0,05	0,39 ± 0,05	0,43 ± 0,05	0,78 ± 0,11	0,97 ± 0,24
	subgroup *a*	0,28 ± 0,17**	0,69 ± 0,21*	0,53 ± 0,19	0,79 ± 0,22	1,08 ± 0,33
Ved, m/s	control	0,12 ± 0,06	0,14 ± 0,04	0,18 ± 0,05	0,34 ± 0,07	0,47 ± 0,10
	subgroup *a*	0,10 ± 0,05	0,13 ± 0,04	0,20 ± 0,07	0,37 ± 0,14	0,51 ± 0,16
RI	control	0,68 ± 0,09	0,66 ± 0,08	0,63 ± 0,06	0,50 ± 0,06	0,50 ± 0,04
	subgroup *a*	0,67 ± 0,08	0,65 ± 0,06	0,65 ± 0,07	0,53 ± 0,06	0,52 ± 0,06

Note: *$p < 0.05$; **$p < 0.003$ (the degree of significance is shown compared to the control group).



a *b*

Fig. 1. Patient K., 12 years old. Ultrasonogram of the congenital S-shaped deformity of segment V_1 of the vertebral artery (*a*) and X-ray images of the cervical spine in the anteroposterior and lateral views (*b*). The cervical lordosis is flattened; Kimmerle anomaly

by the neural spines of C_2–C_6. In the subgroup *b* patients with VA deformities in the form of C-tortuosity and an angular bend in segment V_2, ultrasound examination revealed an increase in *Vps* in this segment to 0.69 ± 0.10 m/s ($p < 0.01$), whereas blood flow velocity in the other segments of VA and BA did not differ from the control group (Table 3). X-ray examination at the VA deformity level showed instability of segments C_2–C_3 and C_3–C_4 of the cervical spine predominantly. During the MRI examination, signs of intervertebral disc hydropenia of the unstable segments was revealed. The results of X-ray images and MRI of the cervical spine confirmed extravasal VA compression due to

Table 3

Blood flow velocity of the vertebral arteries and basilar artery in children with C-shaped deformity and angular bend of segment V_2 of the vertebral artery ($n = 68$; $M \pm m$)

Blood flow velocity	Groups	Segment V_1	Segment V_2	Segment V_3	Segment V_4	Basilar artery
Vps, m/s	control	0,38 ± 0,05	0,39 ± 0,05	0,43 ± 0,05	0,78 ± 0,11	0,97 ± 0,24
	subgroup *b*	0,38 ± 0,07	0,69 ± 0,10*	0,53 ± 0,19	0,79 ± 0,22	1,08 ± 0,33
Ved, m/s	control	0,12 ± 0,06	0,14 ± 0,04	0,18 ± 0,05	0,34 ± 0,07	0,47 ± 0,10
	subgroup *b*	0,11 ± 0,05	0,15 ± 0,04	0,20 ± 0,07	0,37 ± 0,14	0,51 ± 0,16
RI	control	0,68 ± 0,09	0,66 ± 0,08	0,63 ± 0,06	0,50 ± 0,06	0,50 ± 0,04
	subgroup *b*	0,66 ± 0,08	0,67 ± 0,06	0,65 ± 0,07	0,53 ± 0,06	0,52 ± 0,06

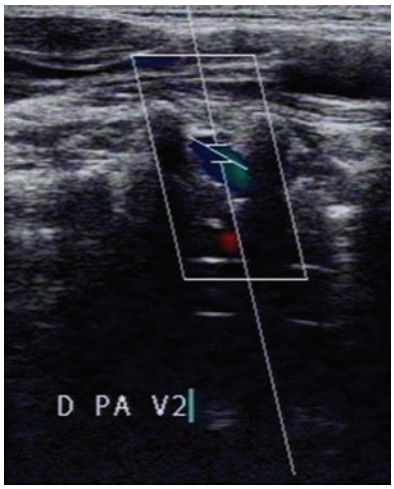
Note: *$p < 0.01$ (the degree of significance is shown compared to the control group).

Table 4

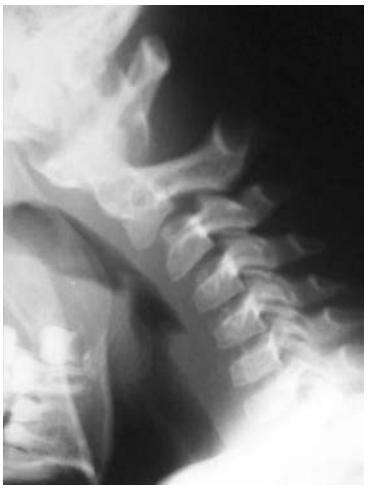
Blood flow velocity of the vertebral arteries and basilar artery in children with excessive tortuosity of segment V_3 of the vertebral artery ($n = 11$; $M \pm m$)

Blood flow velocity	Groups	Segment V_1	Segment V_2	Segment V_3	Segment V_4	Basilar artery
Vps, m/s	control	0,38 ± 0,05	0,39 ± 0,05	0,43 ± 0,05	0,78 ± 0,11	0,97 ± 0,24
	subgroup *c*	0,39 ± 0,07	0,51 ± 0,12	0,72 ± 0,23*	0,63 ± 0,23	1,02 ± 0,31
Ved, m/s	control	0,12 ± 0,06	0,14 ± 0,04	0,18 ± 0,05	0,34 ± 0,07	0,47 ± 0,10
	subgroup *c*	0,12 ± 0,05	0,15 ± 0,04	0,30 ± 0,07*	0,21 ± 0,04	0,53 ± 0,14
RI	control	0,68 ± 0,09	0,66 ± 0,08	0,63 ± 0,06	0,50 ± 0,06	0,50 ± 0,04
	subgroup *c*	0,68 ± 0,08	0,69 ± 0,07	0,66 ± 0,09*	0,64 ± 0,09	0,55 ± 0,06

Note: * $p < 0.01$ (the degree of significance is shown compared to the control group)



a



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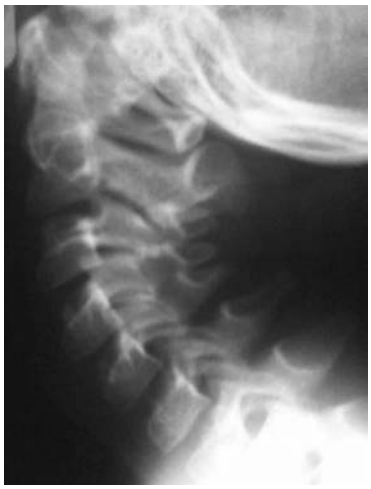
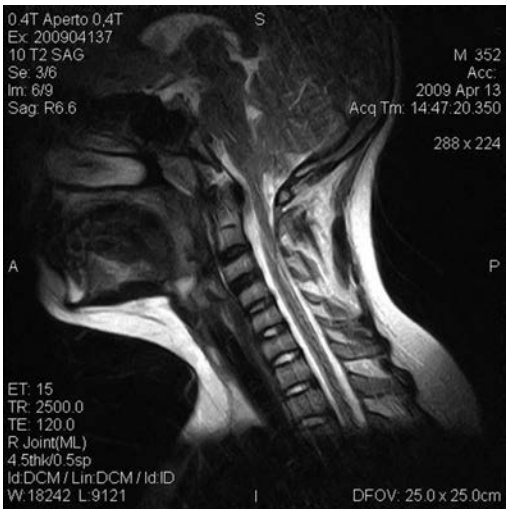
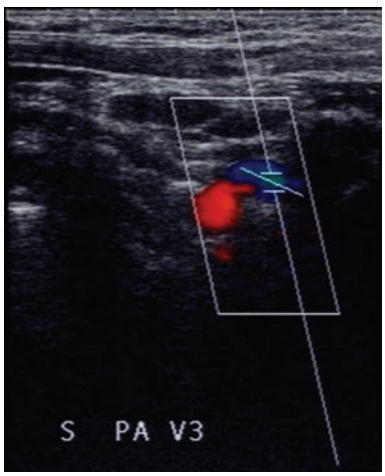


c

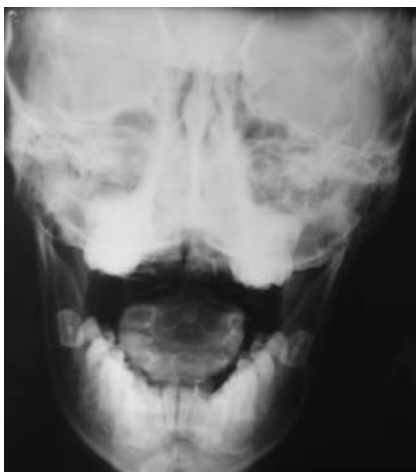


d

Fig. 2. Patient M., 9 years old. Ultrasonogram of the acquired deformity of vertebral artery segment V_2 on type of corner bending in the projection of the vertebral-motor segment C_3–C_4 of the cervical spine (*a*); functional X-ray image of the cervical spine at maximum flexion; the relationships of bone structures are not impaired (*b*); functional X-ray image of the cervical spine at maximum extension; dislocation of the C_3 vertebra posteriorly by 3.5 mm (*c*) is detected; magnetic resonance tomography of the cervical spine; MRI signs of intervertebral disc hydropenia of segments C_2–C_3 and C_3–C_4 (*d*) are detected



a



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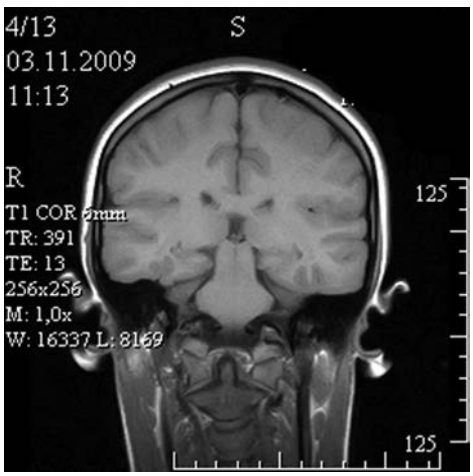


c

Fig. 3. Patient B., 12 years old. Ultrasonogram of the acquired kinking deformity of the V_3 segment of vertebral artery (*a*); X-ray images of the cervical spine through the open mouth revealed asymmetric position of the odontoid process of C_2 relative to the lateral mass of the atlas (*b*); magnetic resonance tomography of the cervical spine showed MRI signs of atlas rotary subluxation (*c*)

the influence of bone structures (Fig. 2*a*, *b*, *c*, *d*).

The excessive tortuosity of the V_3 segment, enveloping the first cervical vertebra, was diagnosed by duplex study of 11 VAs. With this form of VA deformity, there was an increase of *Vps* to 0.72 ± 0.23 m/s ($p < 0.002$) in this segment, an increase of *Ved* to 0.30 ± 0.07 m/s ($p < 0.01$), and increase of RI to 0.66 ± 0.09 m/s ($p < 0.005$) compared to the controls. The rest of the blood flow velocities for segments V_1, V_2, and V_4 of VA and BA did not differ from the control group (Table 4).

Loop-type deformities were found in 10 VAs. This tortuosity of VA was accompanied by a significant decrease in *Vps* of segment V_3 to 0.31 ± 0.13 m/s ($p < 0.002$), a decrease in *Ved* to 0.10 ± 0.04 m/s ($p < 0.03$), and an increase in *Vps* of segment V_4 to 1.17 ± 0.33 m/s ($p < 0.001$). *Ved* increased to 0.55 ± 0.07 m/s ($p < 0.0006$); *Vps* acceleration in the BA increased to 1.45 ± 0.34 m/s ($p < 0.002$); and *Ved* increased to 0.70 ± 0.24 m/s ($p < 0.0001$). Blood flow velocity of the segments V_1 and V_2 did not differ from the control group (Table 5).

Table 5

Blood flow velocity of the vertebral arteries in children with loop deformity of arterial segment V_3, ($n = 10$, $M \pm m$)

Blood flow velocity	Groups	Segment V_1	Segment V_2	Segment V_3	Segment V_4	Basilar artery
Vps, m/s	control	0.38 ± 0.05	0.39 ± 0.05	0.43 ± 0.05	0.78 ± 0.11	0.97 ± 0.24
	subgroup *c*	0.31 ± 0.06	0.48 ± 0.12	0.31 ± 0.13*	1.17 ± 0.33*	1.45 ± 0.34*
Ved, m/s	control	0.12 ± 0.06	0.14 ± 0.04	0.18 ± 0.05	0.34 ± 0.07	0.47 ± 0.10
	subgroup *c*	0.13 ± 0.04	0.14 ± 0.05	0.10 ± 0.04*	0.55 ± 0.06*	0.53 ± 0.14
RI	control	0.68 ± 0.09	0.66 ± 0.08	0.63 ± 0.06	0.50 ± 0.06	0.50 ± 0.04
	subgroup *c*	0.65 ± 0.07	0.67 ± 0.07	0.51 ± 0.07	0.65 ± 0.09	0.55 ± 0.06

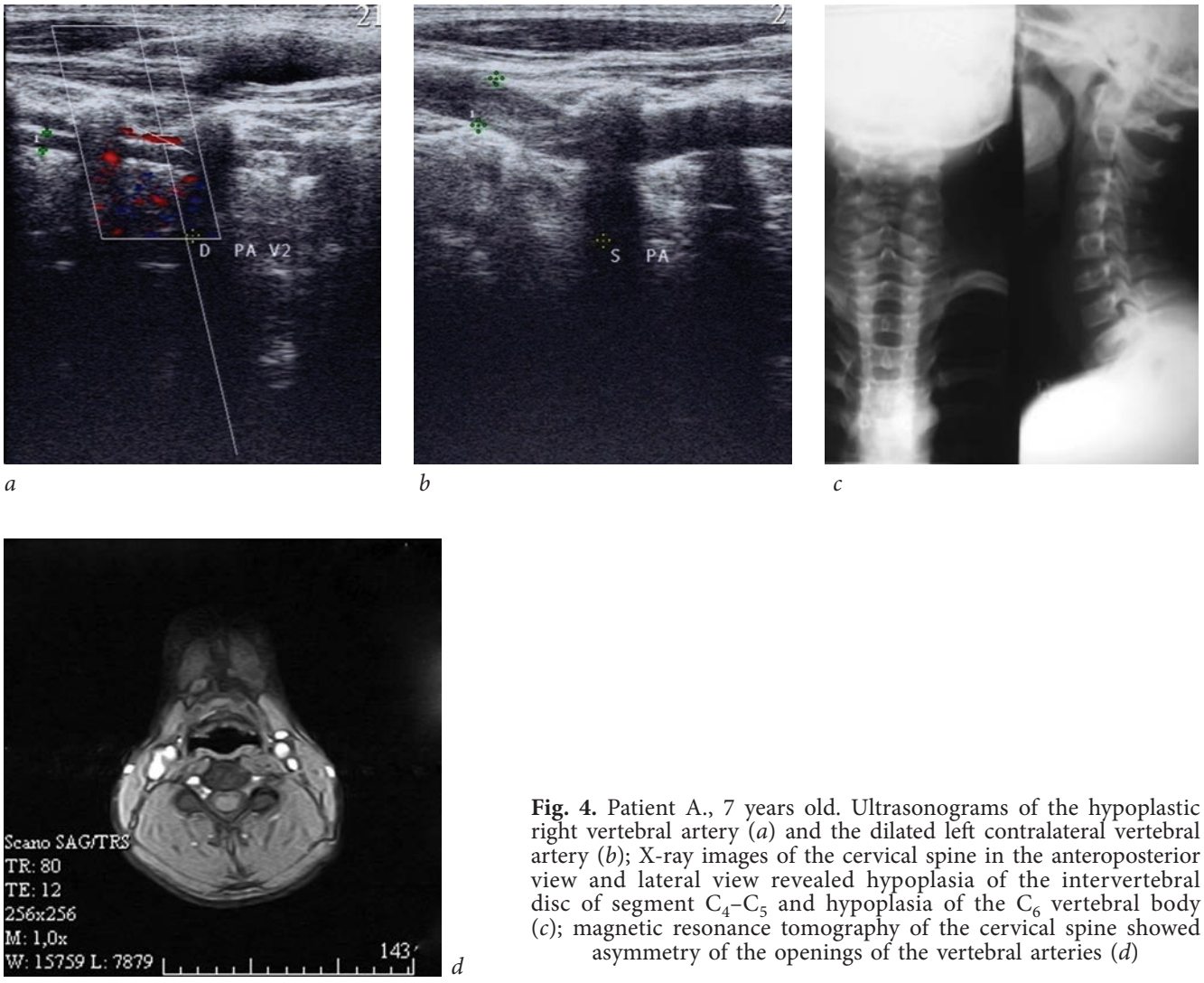
During the X-ray examination, the signs of rotary subluxation of the atlas were revealed in all patients of the subgroup *b* with excessive VA tortuosity; in two patients, they were seen in combination with Kimmerle anomaly. The data obtained showed extravasal VA compression, leading to malperfusion of the vertebral basilar basin (Fig. 3*a, b,* c).

Changes in arterial diameter were found in children with VA lesions of the V_1–V_4 segments (subgroup *d*): the diameter on one side had been reduced 2-fold, while on the other side, it had increased 1.5-fold. Peak systolic blood flow velocity was reduced by 51% in the hypoplastic artery and increased by 32% in the dilated contralateral artery.

On X-ray examination, the malformations were revealed (hypoplasia of the C_6 vertebral body and synostosis of the articular and spinous processes of C_2 and C_3 cervical vertebrae). On MRI, hypoplasia of the C_4–C_5 intervertebral disc and asymmetry of the VA opening diameter were revealed. Thus, the patients had congenital malformations of both soft tissue and bony structures (Fig. 4*a, b, c, d*).

It should be noted that the *Vps* changed for all VA deformities, but the nature of these changes over the vessel length had special characteristics. In children with cervical pain syndrome, the values of this index were similar to the control values for the deformity region. With undulating and excessive tortuosity of the artery and angular bend, an increase in *Vps* is seen in C-, S- and loop-deformity, which indicates a reduction in the value of this index. Above the deformity region, a significant increase in *Vps* is registered only in patients with C-, S-, and loop-deformity of VA; in other patients, *Vps* does not differ from the control group.

The results of X-ray examination showed that 87% of cases of cervical pain syndrome in these children were caused by the presence of congenital or acquired VA deformities related to the instability of vertebral-motor segments C_2–C_3 and C_3–C_4, congenital abnormalities, including Kimmerle anomaly, synostosis of the articular and spinous processes of C_2 and C_3, hypoplasia of the C_6 vertebral body and intervertebral disc C_4–C_5, hypertrophy of the transverse processes of the C_7, rotary subluxation of the atlas, and impairments of the physiological bend of the cervical spine. MRI of the cervical spine, performed after the radiologically diagnosed instability of segments C_2–C_3 and C_3–C_4, and the extravasal compression of VA segment V_2, identified by dopplerography, revealed signs



a *b* *c* *d*

Fig. 4. Patient A., 7 years old. Ultrasonograms of the hypoplastic right vertebral artery (*a*) and the dilated left contralateral vertebral artery (*b*); X-ray images of the cervical spine in the anteroposterior view and lateral view revealed hypoplasia of the intervertebral disc of segment C_4–C_5 and hypoplasia of the C_6 vertebral body (*c*); magnetic resonance tomography of the cervical spine showed asymmetry of the openings of the vertebral arteries (*d*)

of hydropenia of the cervical spine intervertebral discs, usually in children older than 7 years.

Thus, the features underlying the changes in VA blood flow reflect the nature of the arterial lesions and enable assessment of the congenital or acquired genesis of their deformity. Thus, the congenital genesis of segment V_1 deformity in the form of C- and S-shaped VA deformities manifests as *Vps* slowdown in segment V_1 and acceleration in segment V_3. The congenital VA deformity in the form of a loop-type for segment V_3 manifests as a decrease in *Vps* and *Ved* in this segment and an increase in *Vps* and *Ved* in segment V_4 of the VA and BA.

Acquired deformities in the form of an undulating tortuosity and an angular bending in segment V_2 were characterized by acceleration of *Vps* in this segment. The excessive tortuosity of segment V_3 was characterized by an increase in *Vps*, *Ved*, and *RI* in this segment.

In the case of congenital VA hypoplasia for segments V_1–V_4, compensatory expansion of the contralateral homonymous artery occurs.

Conclusions

1. A comprehensive study using radiation methods of examination (duplex scanning of VA, X-ray imaging, and MRI if necessary) for the cervical spine in pediatric patients with cervical pain syndrome enabled the determination that 87% of cases were caused by congenital and acquired changes in the bone and soft tissue structures of the cervical spine.

2. The results of duplex scanning of the VA in cases of cervical pain syndrome are an indication for special methods of X-ray imaging (functional tests in the position of flexion and extension of the neck and transoral X-ray imaging) to detect instability of the vertebral-motor segments of the cervical spine, congenital anomalies of vertebrae development, rotary subluxation of the atlas, and status of the intervertebral discs.

3. The intensity of hemodynamic disorders in the cervical spine of pediatric patients depends on the pathological process of localization in the VA.

4. In cases of complete congenital lesion of all the VA segments on one side (hypoplasia), the contralateral artery is always part of the pathological process as that is where the compensatory dilatation develops.

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