SYMPTOMATIC AND AGGRESSIVE VERTEBRAL HEMANGIOMAS IN CHILDREN: FEATURES OF MODERN INTERPRETATION AND TREATMENT TACTICS

***D.B. Malamashin*[1], *A.Yu. Mushkin*[1, 2]**
[1]*St. Petersburg Research Institute of Phthisiopulmonology, St. Petersburg, Russia*
[2]*Pavlov First Saint Petersburg State Medical University, St. Petersburg, Russia*

Objective. To analyze the features of clinical-radiological manifestations of symptomatic vertebral hemangiomas in children and the possibility of algorithmizing their treatment.
Material and Methods. As part of a monocenter cohort, 24 children aged 4 to 17 years received treatment for symptomatic vertebral hemangiomas. The clinical-radiological manifestations of the tumor and the effectiveness of various methods of invasive treatment were evaluated.
Results. Symptomatic uncomplicated and complicated vertebral hemangiomas, corresponding to stages S2 and S3 of the Enneking classification for benign tumors, occur in children with almost equal frequency. For tumors without extravertebral spread, a closed percutaneous vertebroplasty provides stable relief of complaints. For aggressive hemangiomas with extravertebral, including epidural, spread, various treatment methods are used. An algorithm for choosing therapeutic tactics is proposed.
Conclusion. Surgical treatment of symptomatic vertebral hemangiomas should be carried out using a tactical algorithm that takes into account the stage of the tumor (S2 or S3) and the possibility of performing closed or open vertebroplasty, selective arterial embolization and decompression and stabilization operations on the spine.
Key Words: spine, vertebral hemangioma, selective embolization, vertebroplasty, children.
Please cite this paper as: *Malamashin DB, Mushkin AYu. Symptomatic and aggressive vertebral hemangiomas in children: features of modern interpretation and treatment tactics. Russian Journal of Spine Surgery (Khirurgiya Pozvonochnika). 2024;21(1):63–72. In Russian.*
DOI: http://dx.doi.org/10.14531/ss2024.1.63-72.

Hemangioma is the most common benign bone tumor, which is a proliferation of blood vessels of different calibres lined with a single layer of flattened endothelial cells. Moreover, symptomatic hemangiomas account for less than 1% of primary bone tumors [1]. Most hemangiomas are diagnosed in middle or old age, with the highest incidence in the fifth decade of life, and there is a slight predominance of women (M:F ratio of 0.7:1.0). [2, 3].

Vertebral hemangioma is one of the most frequent benign vertebral tumors of vascular origin. It is believed that hemangiomas are based on disorders of dysembryogenesis nature affecting the proper differentiation of blood vessels [4]. Therefore, some researchers describe a vertebral hemangioma not as a tumor, but rather as a congenital vascular malformation – a hamartoma [5], which is tissue that grows at a normal rate but in an abnormal manner. The incidence of vertebral hemangiomas in the adult population is estimated at 10–26 % [6, 7], but only 0.9–1.2 % have clinical manifestations [8].

The main technique for the primary diagnosis of vertebral hemangiomas remains radiological (X-ray, CT and MRI). In the vast majority of cases, hemangiomas are focal in origin. They are asymptomatic, which, according to the Enneking staging system (ESS) for benign spinal tumors, corresponds to the latent stage (ESS S1) and requires only observation [9, 10]. In the case of symptomatic spinal hemangiomas in 55 % of patients, the only symptom is pain, which is regarded as a sign of non-aggressive but clinically active tumor (ESS S2); the remaining 45 % are presented with an aggressive type (ESS S3) with possible invasion into the paravertebral space or spinal canal, which results in a neurologic deficit [4, 10–13].

There is no data on the incidence of vertebral hemangiomas in the paediatric population; articles are presented by separate clinical case studies. The relative rarity of this tumor in children and the lack of treatment strategies at the ESS S2 and S3 stages restrict our understanding of the course of the disease and treatment options in children.

The objective is to analyse the features of clinical and radiological manifestations of symptomatic vertebral hemangiomas in children and the possibility of algorithmizing their treatment.

Study design: a retrospective monocenter cohort clinical study.

Material and Methods

According to the retrospective database of patients with spinal tumors in the Clinic of Surgery and Paediatric Orthopaedics of the St. Petersburg Research Institute of Phthisiopulmonology in 2005–2022,

24 children were treated for symptomatic vertebral hemangiomas. Considering the rather long (17 years) period of data selection, the tactical approaches and treatment options for patients have changed considerably, which has affected the variety of surgical procedures used.

During the study, data from medical records, operative notes, imaging data, and pathological conclusions of the patients included in the study were assessed.

In addition to formal data (age and gender of the patient, localization of the lesion), clinical and anamnestic indicators were studied: the main manifestations of the disease, the duration of the therapeutic pause and neurological functions in accordance with the modified Frankel scale (now referred to as the ASIA Impairment Scale).

According to the imaging data, an analysis of the prevalence of the pathological process was performed.

Information concerning perioperative management was evaluated: the type of surgery, the duration of the surgery, intraoperative blood loss (circulating blood volume (CBV) deficiency), and complications. In this study, a deficiency of CBV was used to evaluate the blood loss volume. The assessment of blood loss without considering the child's body weight is non-diagnostic, since there are considerable differences in body weight in children of different ages (a 4-year-old patient has a body weight of 18 kg, a 17-year-old patient has 83 kg).

All patients underwent standard radiography of the spine (2 planes), CT and MRI, according to which the stage of spread was defined in compliance with the Enneking classification.

Persistent pain syndrome, the severity of which was evaluated by a 10-point VAS scale, and the presence or deterioration of neurological disorders were indications for surgical treatment. The basis for defining a surgical strategy option was the clinical picture of the disease and its imaging manifestations. Patients with atypical imaging data underwent transcutaneous needle biopsy under C-Arm radiological control.

Postoperative follow-up of patients was performed for periods of 3, 6 and 12 months after the surgery, and then once a year. A standard radiological study was performed after 3 months. An MRI was performed at 6 and 12 months, then once a year for the first three years after treatment. A CT scan with intravenous contrast and an MRI were recommended in cases of complaints indicating a possible recurrence of the tumor, regardless of the period of follow-up.

Statistical analysis was performed using "SPSS Statistics," version 26. Each sample under study, which included less than 50 cases, was assessed for compliance with the normal distribution law using the Shapiro-Wilk test. In the case of a normal distribution, the variables were characterized in the arithmetic mean (M) and standard deviation (±SD) form with a 95% confidence interval (95% CI); the median (Me) and the interquartile range [IQR] were used in the case of an abnormal distribution. The differences in the indicators were recognized as statistically significant at $p < 0.05$.

Results

The analysis included data from 10 boys and 14 girls (42 and 58 %, respectively); the mean age (M ± SD) was 13.70 ± 3.07 years (95 % CI: 12.40–15.01); the minimum was 4 years, the maximum was 17 years, including 4 children under 10 years old and 20 children over 10 years old with a median (Me [IQR]) of 14.5 [12–16] years (Fig. 1). The age structure of the sample indicates the predominance of symptomatic vertebral hemangiomas in adolescents.

Most of the hemangiomas (19 out of 24; 79 %) were localized in the thoracic vertebrae, and in the lumbar vertebrae in 5 patients. Patients with cervical vertebral lesions were not included in the study.

In 7 (29 %) patients, the onset of clinical manifestations of the disease was preceded by a registered fact of injury. Moreover, the presence of persistent, hardly suppressed by NSAIDs vertebrogenic pain syndrome with an intensity of 3 to 5 points according to VAS at the time of admission to the hospital was noted in 18 patients. Neurological disorders corresponding to types B and D by the Frankel scale were found in 6 patients (4 girls and 2 boys).

Thirteen (54 %) cases corresponded to ESS S2 criteria (active or symptomatic non-aggressive benign tumors) and 11 (46 %) corresponded to S3 criteria (aggressive, complicated course).

During the comparison of clinical and anamnestic indicators between patients with aggressive (complicated) and symptomatic (uncomplicated) hemangiomas (ESS S3 vs ESS S2, based on imaging characteristics), significant differences were found in the duration of the treatment pause and the length of hospital stay, as measured by the Mann-Whitney U test ($p = 0.035$ and $p < 0.001$, respectively; Table).

In aggressive hemangioma, the therapeutic pause was half as long as in symptomatic one (median 150 and 300 days, respectively), while the duration of hospital stay was 4.7 times longer (median 47 and 10 days, respectively). This can be explained by the more severe condition of patients, the severity of clinical symptoms, the scope of treatment and postoperative rehabilitation.

No significant differences were found in the comparison groups when studying the remaining indicators.

Atypical imaging manifestations of hemangiomas were detected in 11 (46 %) of 24 patients, which was an indication for percutaneous needle biopsy to exclude the malignant process. The morphological diagnosis was established in six (55 %) cases. The diagnosis was not pathologically verified in 5 (45 %) patients; there were connective tissue and peripheral blood cells without atypia in the biopsy material, which was regarded as the lack of a malignant process and was an indication for further surgical treatment.

In 13 children with symptomatic complicated hemangiomas, the main treatment method was transcutaneous cement vertebroplasty under C-arm radiological control. As an independent procedure, the surgery was successfully performed on 10 patients. The mean surgery duration was 38.00 ± 5.87 minutes. In all patients, a considerable reduction in pain syndrome was achieved already

in the early postoperative period – up to 1 point of VAS with a complete regression of vertebrogenic pain syndrome within 3 months. Selective angiography with embolization was performed in two patients 2 and 4 days before transcutaneous vertebroplasty; in both cases, complete regression of pain syndrome and absence of recurrence were stated within one year and 9 years, respectively. There were no complications after vertebroplasty. An example of vertebroplasty is presented in Fig. 2.

In one case, after a percutaneous needle biopsy, the parents refused to perform subsequent surgery. Unfortunately, further contact with the patient was lost.

Six (25 %) patients underwent preoperative aortography with selective embolization of the vascular network of the tumor in order to prevent blood loss at the upcoming surgical site. The algorithm we currently use for the treatment of hypervascular spinal tumors in children when detecting a pronounced extravertebral component of a tumor with an extensive tumor vasculature according to CT angiography and MRI includes selective angiography with embolization (SAE). Tumor ossification and regression of the extravertebral soft tissue component are the results of the use of SAE, and a reduced severity of pain syndrome, according to VAS, is possible after a single procedure. A contraindication to SAE is the presence of collaterals to the spinal cord in the arteries supplying the tumour.

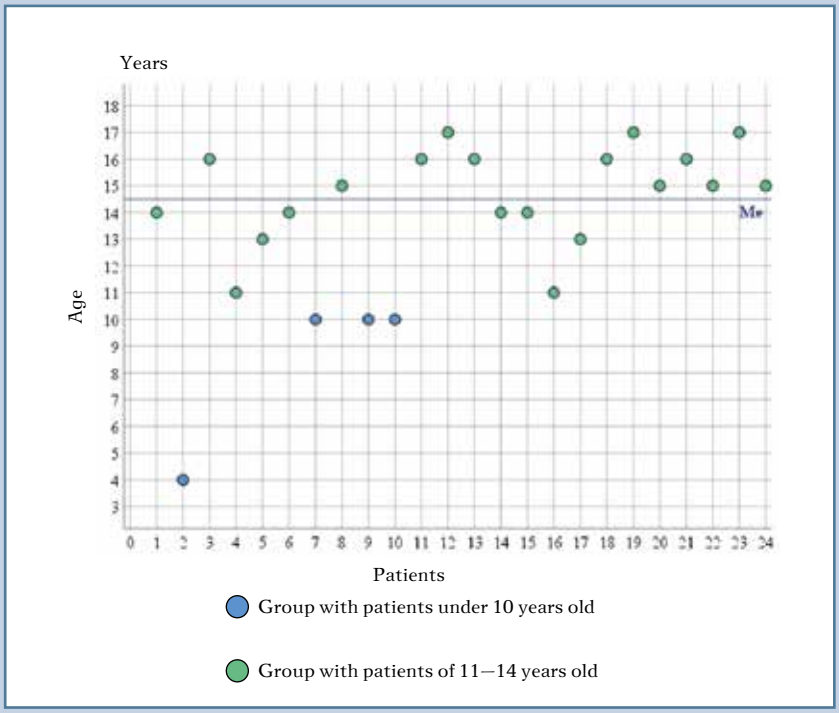

Fig. 1
Distribution of patients by age in the two study groups

The treatment of aggressive complicated hemangiomas (11 patients) is much more complicated because of the lack of clear treatment algorithms and the choice of treatment strategies

Table
Clinical and anamnestic features of children with aggressive (complicated) and symptomatic uncomplicated vertebral hemangiomas

Indicators	Aggressive hemangioma (n = 11)		Symptomatic hemangioma (n = 13)		p
Patients' age, years	Me [IQR]	min–max	Me [IQR]	min–max	0.198
	14 [10.5–15.5]	4–17	15 [14–16]	10–17	
Therapeutic pause, days	Me [IQR]	min–max	Me [IQR]	min–max	0.035*
	150 [105.0–210.0]	30–540	300 [240–360]	30–1080	
Length of hospital stay, days	Me [IQR]	min–max	Me [IQR]	min–max	<0.001*
		13–95	10 [8–16]	2–30	
Gender, n (%)					
Female	8 (72.7)		6 (46.2)		0.240
Male	3 (27.3)		7 (53.8)		
Tumor localization, n (%)					
Thoracic spine	10 (90.9)		9 (69.2)		0.327
Lumbar spine	1 (9.1)		4 (30.8)		
Presence of injury, n (%)	5 (45.5)		2 (15.4)		0.182

* Differences are statistically significant (p < 0.05).

depending on the severity and duration of neurological disorders.

In one case, surgical treatment included open cement vertebroplasty as well as decompression and reconstruction surgery with the removal of a vertebral tumor, anterior and posterior stabilization of the spine under the same anaesthesia. The surgery duration was 270 minutes; the CBV deficit was 3 %. The neurological status before and after surgery corresponded to type E by the Frankel scale.

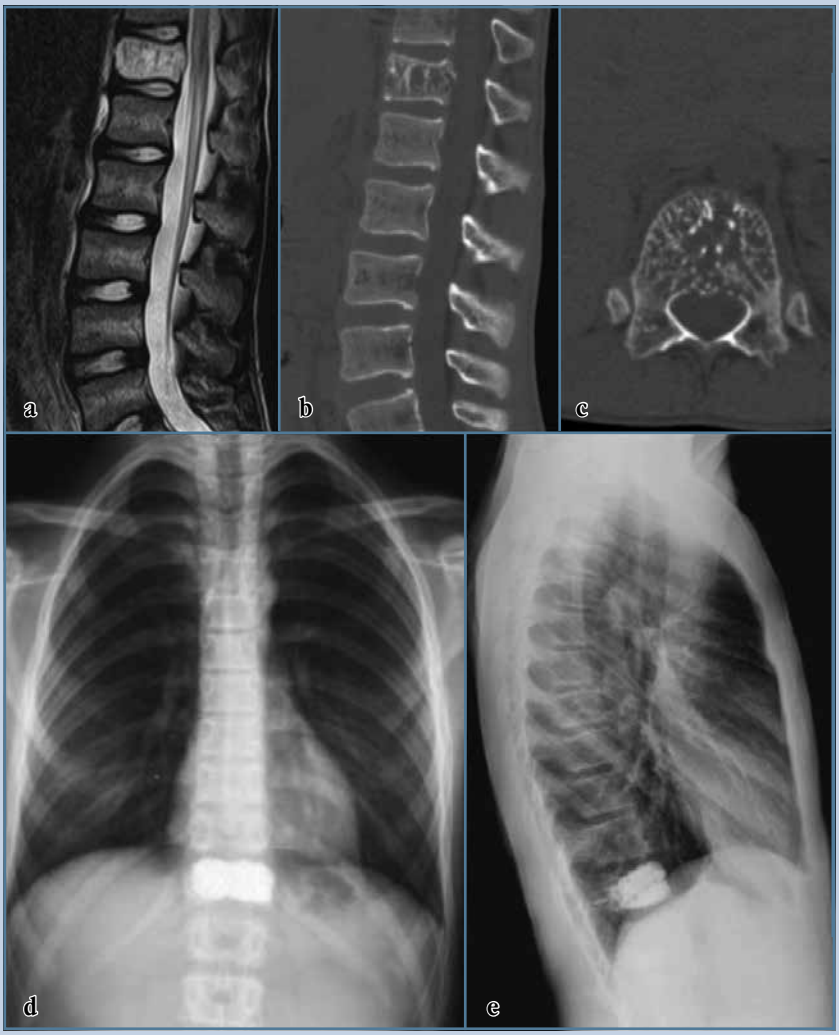

Fig. 2
Uncomplicated aggressive hemangioma of the T12 vertebra in a 13-year-old patient: MRI of the lumbar spine in the sagittal plane **(a)**; CT scan of the lumbar spine in the sagittal plane showing osteolysis of the vertebral body in combination with hypertrophy of the remaining bone trabeculae **(b)**, in the axial plane - honeycomb appearance or polka dot sign **(c)**; the result of transcutaneous cement vertebroplasty of the T12 vertebra on radiographs in frontal **(d)** and lateral **(e)** planes. Clinical complaints: back pain for 6 months with the severity up to 5 points on VAS with complete relief after vertebroplasty; follow-up up to 12 months with full preservation of the result

One child underwent SAE, followed by simultaneous open cement vertebroplasty as well as decompression and reconstruction surgery in one session. The surgery duration was 305 minutes; the CBV deficit was 14 %. Neurological disorders in the early postoperative period were without changes (type D according to the Frankel scale).

The 360° decompression and reconstruction surgeries are technically difficult and are accompanied by significant blood loss. All such surgeries were performed in the first years of the study, including in the absence of the possibility of SAE.

In six cases, the procedure was performed as an independent treatment technique. The mean surgery duration was 252.5 ± 28.9 minutes; the mean blood loss volume was 23.5 ± 6.4 % of the CBV. In one case, SAE was not performed because of anastomoses detected during angiography between the vessels supplying the hemangioma of the T8 body and the spinal artery. Three patients suffered from neurological disorders prior to surgery. After surgery, there were negative changes in one case (an increase in motor disorders from type D to type A according to the Frankel scale) associated with the syndrome of the radiculomedullary artery; there was a partial regression of disorders in the second case (from type B to type D according to the Frankel scale); and the neurological status did not changed in the third case (type D according to the Frankel scale).

The 360° reconstruction was performed prior to SAE in three patients. After SAE, the mean surgery duration was 321.4 ± 52.0 minutes, and the mean intraoperative blood loss volume was 49.6 ± 21.9 % of the CBV (therefore, SAE is ineffective). Two patients before surgery had a neurologic deficit with multidirectional changes after surgery: complete regression in one case (type D according to the Frankel scale before surgery; type E after surgery); and temporary deterioration in the second case (type B according to the Frankel scale before surgery; type A one month after surgery; type B one year after). In another case,

the postoperative onset of neurologic deficit was noted, followed by positive changes: type E according to the Frankel scale before surgery, type C by the Frankel scale one month after surgery, and type D by the Frankel scale one year later. An example of two-stage treatment of aggressive complicated vertebral hemangioma of the T9 vertebra in combination with SAE and subsequent spinal reconstruction is shown in Fig. 3, 4.

Therefore, 7 of 11 patients with aggressive complicated hemangioma had neurological disorders (Fig. 5). Their regression was observed in two patients, while the positive change was already observed one month after treatment and remained at the same level for a year. There was no change in the neurological status in two cases. In one case, a temporary deterioration was noted, followed by a return to the preoperative neurological status; there was no reversion of motor functions to the preoperative level in two patients with worsening signs of myelopathy in the early postoperative period. The minimum duration of long-term follow-up was 10 months, the maximum one was 13 years, no recurrence of the tumor process was noted.

Discussion

The term "aggressive hemangioma" reflects the complex of clinical and imaging manifestations of a tumor. There are several classifications for determining its aggressive origin.

Laredo et al. [14] analysed the imaging characteristics of adult patients with solitary hemangiomas and identified six features. These include the location at the level of T3–T9 vertebrae, total lesion of the vertebral body, the spread of the tumor process to the pedicle and arch of the vertebra, bone expansion with protrusion of the cortical layer with indistinct borders, the uneven trabecular structure of the hemangioma, and the epidural or paravertebral component of the tumor. Hemangioma was considered aggressive in the presence of three or more signs [14].

According to the radiological features, Gaudino et al. [15] identified three types of vertebral hemangioma: typical, atypical and aggressive [15]. The authors classified cavity (cavernous) tumors without characteristic imaging signs as atypical. These include underlined vertical trabeculae, honeycomb appearance, and/or the polka dot sign [15, 16], usually registered in aggressive vertebral hemangiomas. At the same time, atypical vertebral hemangiomas are usually latent (ESS1 S1), and the absence of typical manifestations of vertebral hemangioma may result in a misdiagnosis [16, 17].

The classification signs that define two clinical variants of the tumor (asymptomatic and symptomatic) with a definition of a non-aggressive and aggressive clinical and imaging course for vertebral hemangiomas has been clarified [18]. The most severe variant (symptomatic aggressive vertebral hemangiomas) includes two subtypes: with or without an epidural component.

In order to clarify the localization, prevalence, and presence of extravertebral spread, CT and MRI are used. On MRI, the hemangioma is usually characterized by high signal intensity in T1- and T2-weighted sequences [19]. Atypical hemangioma is manifested on CT by osteolysis of the vertebra in combination with hypertrophy of preserved bone trabeculae; extravertebral spread is manifested with a paraosseous mass effect on MRI and extremely rarely with a pathological vertebral fracture [20].

In modern domestic practice, an adult-patient-centered scale for evaluating the aggressive nature of vertebral hemangiomas, including nine radiological and clinical criteria, has found wide application [21, 22]. Two forms of aggressive hemangiomas are identified to stan-

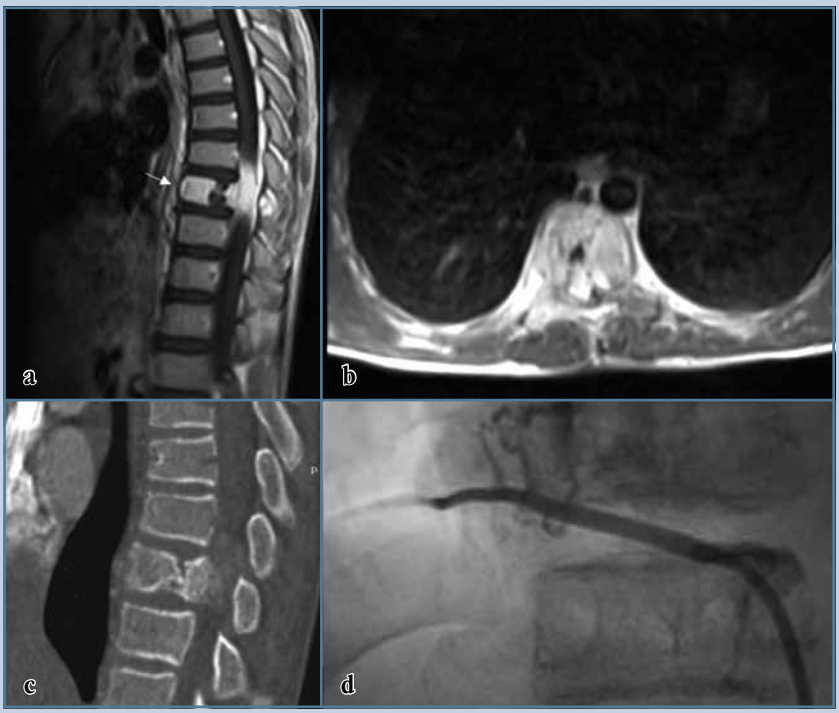

Fig. 3
Complicated aggressive hemangioma of the T9 vertebra with an epidural component in a 16-year-old patient: MRI of the thoracic spine with compression of the dural sac of the spinal cord at the T9 level **(a, b)**; CT scan of the thoracic spine with osteolysis of the T9 vertebra in combination with spinal canal stenosis **(c)**; selective angiography with embolization of the T9 vertebra **(d)**

Fig. 4
The result of surgical treatment of a complicated aggressive hemangioma of the T9 vertebra with an epidural component: the stage of decompression of the dural sac of the spinal cord, the tumor tissue is indicated by arrows **(a)**; postoperative radiographs of the thoracic spine in direct **(b)** and lateral **(c)** planes after two-stage surgical treatment (selective angiography with embolization + 360° reconstruction)

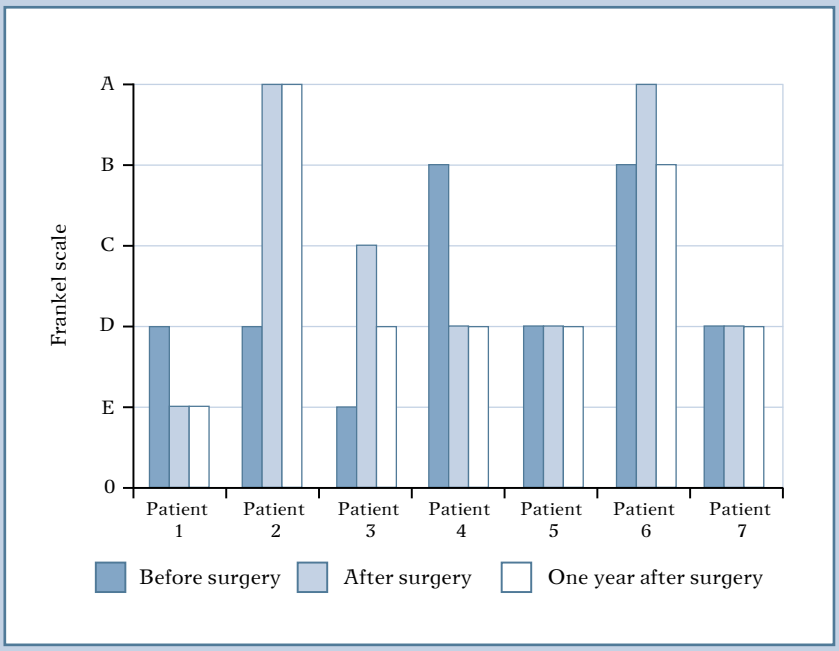

Fig. 5
Neurological changes according to the Frankel scale in patients with aggressive complicated hemangioma

dardize medical practice: uncomplicated and complicated. The first one has no extravertebral spread or compression of neural structures, and its clinical signs are limited to local pain syndrome. Complicated aggressive hemangioma is marked by the presence of an extravertebral component and clinical manifestations of compression both of the spinal cord and spinal nerves. Therapeutic strategies for aggressive vertebral hemangiomas are defined by clinical manifestations.

The analysis of our cohort of children with aggressive vertebral hemangiomas enables us to draw attention to some peculiarities of the pathology interpretation and treatment strategy.

Asymptomatic inactive (latent or S1 according to the ESS) hemangiomas, which do not require treatment and for which over-time MRI monitoring is sufficient, are outside the scope of this study. The clinical interpretation of aggressive vertebral hemangiomas is quite different from the radiological one. On the one hand, an uncomplicated symptomatic (clinically aggressive) vertebral heman-

gioma without an extravertebral component corresponds to an active tumor according to ESS for benign lesions and may be marked as S2. On the other hand, a clinically asymptomatic (accidental imaging finding), but increasing in size under dynamic control and remaining within the vertebral body (intracorpartmental) tumor according to imaging signs should also be considered and marked as active one. This poses a tactical dilemma: either to continue the observation with an unclear answer to the question "how long?" or to perform vertebroplasty with the potential risk of peri-manipulation complications in the initial clinical absence of symptoms. Perhaps, the clinical description of the concept of "symptomatic" for such tumors is sufficient for choosing an active treatment strategy.

Uncomplicated and complicated symptomatic vertebral hemangiomas were found at almost the same rate, amounting to 13 and 11 cases, respectively.

In neither case were vertebral hemangiomas accompanied by a pathological fracture (decrease in height or wedge shape of the vertebral body), resulting in doubt about their etiological significance for this pathology in children.

There are no treatment guidelines for vertebral hemangiomas in children. However, for uncomplicated hemangiomas accompanied only by pain syndrome, the puncture percutaneous vertebroplasty procedure recommended for adults proved to be absolutely effective and provided a stable clinical outcome, especially since most of these patients are teenagers.

The choice of treatment strategy for complicated aggressive vertebral hemangioma is more difficult. In this case, we recommend an algorithm (Fig. 6), which is based on two signs: the presence or absence of neurological disorders and the direction of extravertebral tumor spread (epidural or paravertebral).

Considering modern technologies, we abandoned the 360° reconstruction performed at the initial stages as an independent treatment in favour of less traumatic decompression and stabilization procedures in combination with previous selective arterial embolization and/or open vertebroplasty. Moreover, the opportunities of modern endovascular surgery provide for selective embolization of the main blood vessel in its presence, a small vasculature with a branching type of blood supply to the tumor, or a combination of them. The choice of embolizing material depends on the size of the blood vessel or malformation, as well as on the need for a temporary or permanent outcome of treatment. In the case of an aggressive tumor without neurological complications, such treatment can be used not only as preparation for subsequent surgery, but also as an option for self-treatment, including repeated one, which is used for other hypervascular tumors in children [23].

We cannot ignore the fact that the duration of the therapeutic pause in complicated vertebral hemangiomas proved to be considerably less than in uncomplicated ones. This allows us to consider that the commonly interpreted as successive phases of the tumor stages are actually variants of its course.

Conclusion

Symptomatic vertebral hemangiomas in children are not only quite rare, but also because of the peculiarity of clinical and imaging manifestations require differentiated treatment strategies depending on the aggressive nature of the course and the presence of neurological complications. Meanwhile, the used options for surgical treatments are quite diverse and include SAE, cement vertebroplasty, vertebral reconstruction with anterior and posterior stabilization, spondylectomy, as well as a combination of techniques.

Differentiation of approaches to the treatment of aggressive uncomplicated (ESS S2) and complicated (ESS S3) vertebral hemangiomas in children has shown good long-term outcomes. Meanwhile, the vertebroplasty techniques used in adults proved to be equally effective for uncomplicated symptomatic hemangiomas.

The most radical treatment of complicated vertebral hemangiomas in children is 360° reconstruction. Nevertheless, this

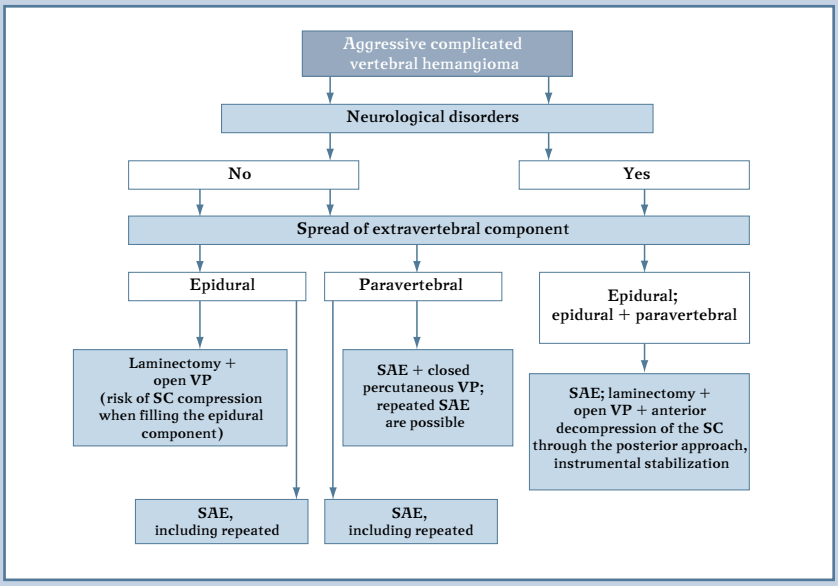

Fig. 6
Algorithm of treatment strategy for patients with complicated aggressive vertebral hemangiomas: VP – vertebroplasty; SAE – selective angiography with embolization; SC – spinal cord

surgery is the most traumatic and may trigger the development of neurological complications. Procedures decreasing tumor vascularization, such as preoperative SAE and intraoperative open (post-laminectomy) vertebroplasty, can improve the visualization of the surgical site, reduce both the traumatic nature of the surgery and the blood loss volume during subsequent instrumental stabilization of the spine.

It is understood that the very fact of neurological disorders associated with compression of the spinal cord by a vascular tumor is a prognostic concern, since in 27% of cases it is accompanied by an aggravation of neurological symptoms after surgery.

The study had no sponsors. The authors declare that they have no conflict of interest.
The study was approved by the local ethics committees of the institutions. All authors contributed significantly to the research and preparation of the article, read and approved the final version before publication.

References

1. **Czerniak B.** Vascular lesions. In: Dorfman and Czerniak's Bone Tumors, 2nd ed. Philadelphia, PA: Elsevier, 2015:903–989.
2. **Adler CP.** Hemangioma of the bone. In: Adler C.P., ed. Bone Diseases. Berlin: Springer, 2000:370–375.
3. **Unni KK, Inwards CY.** Benign vascular tumors. In: Unni KK, Inwards CY. Dahlin's Bone Tumours: General Aspects and Data on 10,165 Cases. 6th ed. Philadelphia, PA: Lippincott Williams & Wilkins. 2010:262–271.
4. **Fox MW, Onofrio BM.** The natural history and management of symptomatic and asymptomatic vertebral hemangiomas. J Neurosurg. 1993;78:36–45. DOI: 10.3171/jns.1993.78.1.0036.
5. **Greenspan A, Remagen W.** Differential Diagnosis of Tumors and Tumor-Like Lesions of Bones and Joints. Philadelphia, 1998.
6. **Acosta FL Jr, Dowd CF, Chin C, Tihan T, Ames CP, Weinstein PR.** Current treatment strategies and outcomes in the management of symptomatic vertebral hemangiomas. Neurosurgery. 2006;58:287–296. DOI: 10.1227/01.NEU.0000194846.55984.C8.
7. **Wang B, Han SB, Jiang L, Liu XG, Yang SM, Meng N, Wei F, Liu ZJ.** Intraoperative vertebroplasty during surgical decompression and instrumentation for aggressive vertebral hemangiomas: a retrospective study of 39 patients and review of the literature. Spine J. 2018;18:1128–1135. DOI: 10.1016/j.spinee.2017.11.003.
8. **Murugan L, Samson RS, Chandy MJ.** Management of symptomatic vertebral hemangiomas: review of 13 patients. Neurol India. 2002;50:300–305.
9. **Enneking WF.** A system of staging musculoskeletal neoplasms. Clin Orthop Relat Res. 1986;(204):9–24.
10. **Dang L, Liu C, Yang SM, Jiang L, Liu ZJ, Liu XG, Yuan HS,Wei F, Yu M.** Aggressive vertebral hemangioma of the thoracic spine without typical radiological appearance. Eur Spine J. 2012;21:1994–1999. DOI: 10.1007/s00586-012-2349-1.
11. **Slon V, Stein D, Cohen H, Sella-Tunis T, May H, Hershkovitz I.** Vertebral hemangiomas: their demographical characteristics, location along the spine and position within the vertebral body. Eur Spine J. 2015;24:2189–2195. DOI: 10.1007/s00586-015-4022-y.
12. **Goldstein CL, Varga PP, Gokaslan ZL, Boriani S, Luzzati A, Rhines L, Fisher CG, Chou D, Williams RP, Dekutoski MB, Quraishi NA, Bettegowda C, Kawahara N, Fehlings MG.** Spinal hemangiomas: results of surgical management for local recurrence and mortality in a multicenter study. Spine. 2015;40:656–664. DOI: 10.1097/BRS.0000000000000840.
13. **Sewell MD, Dbeis R, Bliss P, Watkinson T, Hutton M.** Radiotherapy for acute, high-grade spinal cord compression caused by vertebral hemangioma. Spine J. 2016;16:e195–e196. DOI: 10.1016/j.spinee.2015.10.018.
14. **Laredo JD, Reizine D, Bard M, Merland JJ.** Vertebral hemangiomas: radiologic evaluation. Radiology. 1986;161:183–189. DOI: 10.1148/radiology.161.1.3763864.
15. **Gaudino S, Martucci M, Colantonio R, Lozupone E, Visconti E, Leone A, Colosimo C.** A systematic approach to vertebral hemangioma. Skeletal Radiol. 2015;44:25–36. DOI: 10.1007/s00256-014-2035-y.
16. **Urrutia J, Postigo R, Larrondo R, Martin AS.** Clinical and imaging findings in patients with aggressive spinal hemangioma requiring surgical treatment. J Clin Neurosci. 2011;18:209–212. DOI: 10.1016/j.jocn.2010.05.022.
17. **Alexander J, Meir A, Vrodos N, Yau YH.** Vertebral hemangioma: an important differential in the evaluation of locally aggressive spinal lesions. Spine. 2010;35:E917–E920. DOI: 10.1097/brs.0b013e3181ddfb24.
18. **Kravtsov MN, Manukovskiy VA, Manashchuk VI, Svistov DV.** Association of Neurosurgeons of Russia: Diagnosis and Treatment of Aggressive Vertebral Hemangiomas: Clinical Guidelines. Moscow, 2015.
19. **Jha B, Choudhary AK.** Unusual cause of back pain in an adolescent patient: a case report and natural history of aggressive vertebral hemangioma in children. Pain Physician. 2008;11:687–692.
20. **Wang B, Zhang LH, Yang SM, Han SB, Jiang L, Wei F, Yuan HS, Liu XG, Liu ZJ.** Atypical radiographic features of aggressive vertebral hemangiomas. J Bone Joint Surg Am. 2019;101:979–986. DOI: 10.2106/JBJS.18.00746.
21. **Kravtsov MN, Manukovskii VA, Zharinov GM, Kandyba DV, Tsibirov AA, Savello AV, Svistov DV.** Aggressive vertebral hemangiomas: optimization of management tactics. Zhurnal Voprosy Neirokhirurgii Imeni N.N. Burdenko. 2012;76(2):23–32.
22. Association of Neurosurgeons of Russia. Clinical Guidelines for the Diagnosis and Treatment of Aggressive Vertebral Hemangiomas. Moscow, 2019.
23. **Grigoriou E, Dormans JP, Arkader A.** Primary aneurysmal bone cyst of the spine in children: updated outcomes of a modern surgical technique. Int J Spine Surg. 2020;14:615–622. DOI: 10.14444/7082.

Address correspondence to:
Malamashin Denis Borisovich
St. Petersburg Research Institute of Phthisiopulmonology,
32 Politekhnicheskaya str., St. Petersburg, 194064, Russia,
malamashin@mail.ru

Received 13.11.2023
Review completed 23.12.2023
Passed for printing 28.12.2023

Denis Borisovich Malamashin, MD, PhD, orthopedic surgeon, senior researcher, Clinic of Pediatric Surgery and Orthopedics, St. Petersburg Research Institute of Phthisiopulmonology, 32 Politekhnicheskaya str., St. Petersburg, 194064, Russia, ORCID: 0000-0002-7356-6860, malamashin@mail.ru;
Aleksandr Yuryevich Mushkin, DMSc, Prof., chief researcher, Head of Clinic of Pediatric Surgery and Orthopedics, Head of the Scientific and Clinical Centre for Spinal Pathology, St. Petersburg Research Institute of Phthisiopulmonology, 32 Politekhnicheskaya str., St. Petersburg, 194064, Russia; Professor of the Department of traumatology and orthopedics, Pavlov First Saint Petersburg State Medical University, 6–8 L'va Tolstogo str., St. Petersburg, 197022, Russia, ORCID: 0000-0002-1342-3278, aymushkin@mail.ru.