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MINIMALLY INVASIVE PERCUTANEOUS METHODS OF SURGICAL CORRECTION OF TUMORAL PROCESSES AND PATHOLOGICAL DEFORMITIES IN THE VERTEBRAL BODIES OF THE THORACIC AND LUMBAR SPINE

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Abstract
Vertebral hemangiomas (VH) are benign, slowly progressive vascular tumors arising from capillary and cavernous blood vessels. The social significance of VH is determined by its high prevalence, reaching 10–11% in the general population; the majority of cases occur between the ages of 30 and 60 years, with women accounting for 2/3 of all cases [2, 3].

Introduction
Until recently, the lack of a clear clinical picture complicated the diagnosis of vertebral hemangioma. With the introduction of modern diagnostic modalities into clinical practice — computed tomography (CT), magnetic resonance imaging (MRI), and multislice computed tomography (MSCT) — VH have become a relevant problem in contemporary vertebrology [1, 4]. VH are characterized by polymorphism of clinical manifestations: from asymptomatic course to active clinical forms with a tendency toward rapid tumor growth — the

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so-called aggressive hemangiomas. Aggressive hemangiomas are potentially dangerous due to possible complications: pathological compression fractures of the affected vertebral bodies with epidural extension of the soft tissue component; extradural hematomas due to hemorrhage from the tumor with development of medullary spinal cord anemia; and narrowing of the spinal canal due to hypertrophy of the affected bony tissue of the vertebral body [4, 6].

As a rule, vertebral body hemangiomas are characterized by an asymptomatic course over a prolonged period. Nevertheless, cases of hemangiomas presenting as truly aggressive tumors have been described — in 0.9–4% of observations [5, 6, 13]. Progressive remodeling of the bony architecture leads to weakening of the load-bearing capacity and stability of the vertebra, with reduction of axial resistance. Even minor trauma or heavy lifting may result in disease progression and pathological fracture of the vertebral body with potential development of various neurological disorders. The primary diagnostic modalities for vertebral body hemangiomas are spondylography, CT, and MRI.

Spondylography reveals signs of vertebral body involvement: remodeling of the bone architecture, change in vertebral shape with possible deformity, and allows assessment of the integrity of the end plates and cortical layer. CT identifies cavities in the vertebral bodies in the form of so-called 'honeycomb' pattern — a result of lysis of bony trabeculae — as well as their hypertrophy and possible calcification (the 'peas' sign). A characteristic CT finding of hemangioma is 'ballooning' of the vertebral body. MRI provides additional information about the structure of the hemangioma, about tumor extension beyond the vertebral body with formation of a paravertebral or intracanal soft tissue component, which may be accompanied by spinal cord compression.

Progressive population aging is currently considered a global medical problem according to WHO experts [2]. Vertebral body injuries in elderly and senile patients are generally considered to be a consequence of low-energy trauma due to concomitant osteopenic syndrome [1, 2]. However, increasing social activity

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among older age groups leads to a rise in the number of high-energy injuries. Widely used puncture-based stabilization techniques — vertebroplasty and kyphoplasty — are currently not considered 'standard treatment' by most orthopedic surgeons [7, 8].

Vertebral body deformities are the most common complication of osteoporosis: approximately 1.5 million osteoporosis-related deformities are registered annually in the United States, with an annual incidence of pathological vertebral deformities of approximately 700,000 cases. The true prevalence is likely significantly higher, as such injuries are diagnosed in only 1/3 of cases. Surgical treatment of pathological deformities has become widely adopted, as it promotes rapid, pronounced, and sustained relief of pain, improvement of spinal function, and enhancement of patients' quality of life.

The optimal method of surgical stabilization in the setting of reduced bone mineral density and concomitant pathology in elderly patients remains a subject of debate [1, 4, 9]. Conventional surgical approaches for thoracolumbar fractures — transpedicular fixation via a posterior midline approach, anterior spinal fusion, or their combination — are inappropriate for elderly patients due to high invasiveness, risk of implant instability in osteoporotic bone, and high anesthetic risk [10]. Minimally invasive surgical techniques allow stabilization of the injured spine with minimal trauma. Among the most widespread methods for treating osteoporotic deformities are vertebroplasty and kyphoplasty, which provide effective pain relief, functional improvement, and prevention of further vertebral body compression [3, 5, 6].

Balloon kyphoplasty was first developed in 1998 by American neurosurgeons led by M. Reiley in collaboration with the company 'Kyphon'; the first scientific report was published by W. Wong et al. in 2000. Kyphoplasty is essentially a modified vertebroplasty. Its principal distinction consists in the preliminary introduction of a balloon-tipped guide through a specialized bone needle into the vertebral body: the balloon is inserted in a deflated state and then inflated to

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restore the height of the affected vertebra. An important advantage of kyphoplasty is the significant reduction of the risk of extravertebral cement leakage.
To date, a unified treatment strategy for aggressive hemangiomas has not been established. Nevertheless, most researchers recognize puncture vertebroplasty as a sufficiently effective treatment method for this pathology. The method is minimally invasive, relatively safe, and allows a therapeutic effect to be achieved directly during the surgical intervention [1, 6, 12]. The first introduction of bone cement into a vertebral body was performed by H. Deramond and P. Galibert [7, 8, 9]. Accumulated experience with this type of surgical treatment demonstrates restoration of vertebral load-bearing capacity, cessation of tumor growth, and elimination of pain.

Aim of the Study

To analyze the outcomes of minimally invasive surgical treatment of hemangiomas and osteoporotic deformities of the thoracic and lumbar vertebral bodies using percutaneous vertebroplasty with bone cement.

Materials and Methods

The study material comprised data from 142 patients with aggressive hemangiomas of the thoracolumbar vertebral bodies and 48 patients with osteoporotic vertebral body deformities of the thoracolumbar spine, who underwent percutaneous vertebroplasty with bone cement at the vertebral surgery clinic of the Republican Specialized Scientific-Practical Medical Center of Traumatology and Orthopedics of the Republic of Uzbekistan (Tashkent) between 2016 and 2026. The study group included 57 men and 133 women, with a mean age of 48.8 years (range: 22–79 years).
The mandatory preoperative diagnostic protocol included history taking and clinical examination. The Visual Analogue Scale (VAS) was used to assess the severity of vertebral pain syndrome. Functional adaptation was evaluated using

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the Oswestry Disability Index. The following diagnostic modalities were employed for diagnosis and monitoring of treatment efficacy: radiography, CT, MRI, venospondylography, and others.

VAS was interpreted as follows: 0–5 points — absence of pain or minor discomfort; 6–35 points — moderate pain syndrome; 36–55 points — moderate-intensity pain; 56–75 points — severe pain syndrome; 76 points and above — very intense pain.

Clinical examination included assessment of muscle strength in the extremities (in points), presence of motor and sensory disorders, spinal deformities, range of motion in the spinal motion segment, state of musculotendinous reflexes, and muscle tone. Analysis of concomitant diseases focused on cardiovascular and respiratory system pathology, as well as the presence of other spinal diseases.

Single hemangiomas were detected in 72 (50.8%) patients; 50 (35.4%) patients had hemangiomas at two or more levels; 20 (13.7%) patients had hemangiomas simultaneously in both the thoracic and lumbar spine.

Currently, percutaneous vertebroplasty (PV) is the 'gold standard' for the treatment of uncomplicated aggressive VH. The method consists of injection of bone cement (polymethylmethacrylate) into the lesion cavity. This simultaneously achieves: reinforcement of the vertebra (reduced risk of compression fracture), cytotoxic effect due to chemical interaction between the lesion and cement components, and analgesic effect through partial destruction of pain receptors in the vertebral body. Compared to other techniques, PV significantly accelerates recovery of motor activity, allowing a reduction in the duration of inpatient treatment and a substantial improvement in patients' quality of life.

The primary indication for PV with bone cement is the presence of a vertebral body hemangioma with signs of aggressive behavior leading to vertebral destruction and neural structure compression. The following absolute indications for PV were established:

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• Total and subtotal hemangiomas (involving at least 3/4 of the vertebral body) with high risk of pathological fracture;
• Vertebral body hemangiomas complicated by pathological fracture and deformity.
Relative indications for vertebroplasty included:
• Vertebral body hemangiomas (involving at least 1/3 of the vertebral body) with signs of aggressive behavior;
• Vertebral body hemangiomas with severe pain syndrome when tumor size is less than 1/3 of the vertebral body.
Contraindications to PV included:
• Severe decompensated somatic condition of the patient;
• Coagulopathy: platelet count below 100,000, prothrombin time exceeding 3 times the upper limit of normal;
• Pathological compression fracture of the vertebral body with height reduction exceeding 70%;
• Inflammatory changes of the skin at the planned puncture site and inflammatory spinal diseases;
• Intolerance to bone cement components.
A relative contraindication is disruption of the integrity of the posterior wall of the vertebral body, in order to prevent extravasation of bone cement into the epidural space. In such cases, the final decision is made after thorough analysis of CT or MSCT data.
PV was performed in an operating room equipped with X-ray fluoroscopy and radiation protection. Specialized beveled needles manufactured by Cook (USA) or Stryker (USA), 11G–13G in diameter and 10–20 cm in length, were used for vertebral body puncture. An 11G needle was used for puncture of upper thoracic vertebrae, and 13G for lower thoracic and lumbar vertebrae. The optimal needle diameter was determined at the preoperative assessment stage based on

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spondylography and spinal CT data, with the condition that it did not exceed half the width of the vertebral pedicle.
Several types of bone cement were used for vertebroplasty: 'Surgical Simplex P' (Stryker, USA), 'Spineplex' (Stryker, USA), 'Cemento Fixx' (Synimed, France). All cements are polymethylmethacrylate-based and differ in polymerization time, high viscosity, brief mixing phases, and pronounced exothermic reaction. Component mixing was performed using mixers of bone cement delivery systems (PCD, Stryker, USA) and Somatex mixing systems (Germany), ensuring a homogeneous composite mass with minimal porosity.
The percutaneous vertebroplasty operation comprised three stages:
- Puncture of the vertebral body;
- Intraoperative venospondylography;
- Injection of bone cement into the lesion site.

An important technical point is the insertion of the puncture needle into the vertebral body using a surgical mallet: this forms a dense channel that prevents retrograde migration of bone cement during pressure injection.
The following approaches were used for vertebral body puncture:
- Transpedicular approach;
- Intercostovertebral approach.

The majority of interventions were performed via the transpedicular approach, which minimizes the risk of damage to neural structures and paravertebral vessels. The intercostovertebral approach was used in the upper thoracic spine in the presence of narrow vertebral pedicles, as passage of puncture needles through narrow pedicles risks pedicle fracture and neurological complications.
The second stage of PV was venospondylography — injection of a radiocontrast agent through the needle into the vertebral body under fluoroscopic control. Water-soluble contrast agents 'Omnipaque', 'Ultravist', or 'Triombrast' were used. The procedure was aimed at visualizing the venous collectors of the vertebra and assessing the intensity of venous drainage, which allows prediction of possible

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cement migration. After the operation, the patient remained motionless on the operating table for 10–20 minutes before being transferred to the ward. The total volume of injected cement was 3–6 ml. Patient mobilization was performed 4 hours after the intervention.

Results and Discussion

The severity of vertebral pain syndrome before surgery averaged 46/50 points on the VAS. At 3 months postoperatively — on average 20/25 points; at 6 months — 15/20 points; at 12 months — 10/15 points. Persistence of pain syndrome after vertebroplasty was noted in 23 (18.5%) patients.

Assessment of functional adaptation using the Oswestry questionnaire demonstrated improvement in all patients compared to preoperative values: at 3 months, the mean score decreased from 32.8/34.5 to 18.2/19.0; at 6 months — to 12.8/15.0; at 12 months — to 6.2/8.0. The mean length of inpatient stay was 4 bed-days. Operation duration ranged from 20 to 80 minutes.

Complications related to bone cement injection were detected by postoperative MSCT in 19 patients: cement leakage into the epidural space — in 2, into the intervertebral disc veins — in 6, extravertebrally — in 6, into the intervertebral disc — in 5.

According to CT, bone cement in the vertebral body is characterized by a high-density signal significantly exceeding that of native bone. On MRI, bone cement produces a hypointense signal in both T1- and T2-weighted images. On postoperative MSCT scans, filling of the hemangioma cavity with cement at 80% or more was classified as total. In 92.5% of cases, filling of the hemangioma was considered total. Control CT and MRI performed at 6 months and 1 year postoperatively revealed no signs of continued hemangioma growth or local bone tissue reactions to bone cement in any case.

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Thus, puncture vertebroplasty is a safe and effective minimally invasive surgical treatment method for aggressive hemangiomas of the thoracolumbar spine.

Conclusions

• Reliable diagnosis of vertebral body hemangiomas is achieved through sequential application of radiography, MRI, and CT. CT is the most effective diagnostic method for vertebral hemangiomas: the accuracy of anatomical localization and assessment of bone tissue involvement is 95–100%.

• Indications for PV are total and subtotal vertebral body hemangiomas with persistent pain syndrome, as well as hemangiomas with progressive increase in size during dynamic follow-up and impaired static-dynamic function of the spine.

• Puncture vertebroplasty is a highly effective minimally invasive surgical treatment method for vertebral body hemangiomas: in 94.5% of cases it allows patients to maintain work capacity. In more than 90% of cases, complete regression of pain syndrome is achieved postoperatively.

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