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Diagnostic and Management Options of Osteoblastoma in the Spine

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Background: Osteoblastoma is a rare, benign, osteolytic neoplasm commonly found in the spine in early adulthood. Here, we review the clinical characteristics, radiographic findings, and surgical management of patients with spinal osteoblastoma.

Material/Methods: Thirteen patients with osteoblastoma who underwent surgery at our institute from June 2008 to November 2017 were enrolled in this study. The American Spinal Injury Association (ASIA) impairment scale was used to assess neurological function. All patients were treated with either total excision or intralesional piecemeal excision without postoperative radiotherapy. Clinical efficacy was evaluated by visual analog scale (VAS) scores, the Oswestry Disability Index (ODI) of nerve function, physical and radiographic examinations, bone fusion, and neurologic status.

Results: The follow-up lasted 23–82 months (average, 43.8 months). The average surgical time was 178.1 minutes (range, 100–230 minutes), with an average intraoperative blood loss of 574 mL (range, 230–1100 mL). Postoperatively, VAS scores decreased from 6.2±1.7 to 0.5±0.7 (P<0.001). The preoperative and final ODI scores were 51.1±7.7 and 22.6±4.9, respectively, reflecting a significant decrease (P<0.001). According to the ASIA classification, 3 patients had grade C, 3 patients had grade D, and 7 patients had grade E disease. Three months postoperatively, 1 patient had grade D and 10 patients had grade E disease; ultimately, all cases were grade E disease. Only 1 patient experienced local recurrence and underwent en bloc marginal resection with postoperative radiotherapy. All patients remained neurologically stable without any major complications.

Conclusions: Accurate intraoperative localization with complete resection is the key to preventing recurrence. Aggressive surgical resection can achieve satisfactory clinical and radiographic outcomes.

MeSH Keywords: **Bone Neoplasms • Diagnosis • Osteoblastoma • Spine • Surgical Tape**

Abbreviations: **ODI** – Oswestry Disability Index; **VAS** – Visual analog scale; **ASIA** – American Spinal Injury Association; **CT** – computed tomography; **MRI** – magnetic resonance imaging; **MRA** – magnetic resonance angiography; **ECT** – emission computed tomography; **PET-CT** – positron emission tomography-computed tomography; **STIR** – short time inversion recovery; **DSA** – digital subtraction angiography; **NSAIDs** – nonsteroidal anti-inflammatory drugs

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Background

Osteoblastoma is one of the most typical benign primary bone tumors, with a peak incidence during the second and third decades of life, predominately affecting children aged 10–15 years, and is well known for its osteoblastic and locally aggressive behavior [1,2]. A variety of studies have established that this disease accounts for 1–5% of all benign tumors and 1% of all bone tumors. The most common location of these tumors is within the vertebral column (28–36%), followed by the long bones; lesions in this location are generally observed in the meta-diaphysis [3–7]. Primary osteoblastoma of the spine has a strong predilection for the posterior elements, especially the lamina and pedicles, and accounts for 10% of all osseous spinal neoplasms [5]. In 1956, Jafe [3] and Lichtenstein [8] independently described this lesion as "osteogenic fibromas of bone", and they established benign osteoblastoma as a clinical and morphological entity. Histologically, osteoblastoma is a benign bone-forming tumor similar to osteoid osteoma, although both are variants of the same basic lesional process of osteoblastic derivation. Osteoblastoma is clinically and radiologically more aggressive than osteoid osteoma [2,6,9]. In 1984, a borderline osteoblastic tumor entity called "aggressive osteoblastoma" was introduced by Dorfman and Weiss [4] and was found to be associated with a high recurrence rate and potential for malignant transformation. Despite being benign tumors, osteoblastomas often cause pronounced bone destruction, soft tissue infiltration, and epidural extension. They usually behave aggressively with extensive uncontrollable local recurrence, and even malignant transformation with metastatic disease has been reported [5,10]. Without treatment, distal aggressiveness of the tumor can result in malignant transformation and destruction of the spinal structure, and in the later stages, it is often associated with a high risk of causing neurological deficits [11]. However, osteoblastoma is rather resistant to traditional radiotherapy and chemotherapy. The accepted mainstay of treatment for osteoblastoma involving neurological impairment is surgical resection, which leads to significant reductions in pain and neurological deficits postoperatively [12–14].

Because of the complex anatomy of the spinal column and the low incidence of primary spinal tumors, no standard treatment procedure is available for osteoblastoma of the spinal column. In this study, we present a retrospective review of 13 patients who were admitted to our center and surgically treated in our department between June 2008 and November 2017. We performed aggressive resection and reconstructive surgery to preserve the spinal structure and stability. We describe the clinical and radiologic presentation, surgical strategies, and clinical outcomes associated with these tumors and compare these results with those reported in the literature to investigate the clinical manifestations and surgical outcomes of spinal osteoblastoma. The American Spinal Injury Association (ASIA) system [15] assesses the functional status of the spine. Additionally, visual analog scale (VAS) [16] and Oswestry Disability Index (ODI) [17] scores were used to assess the preoperative general conditions of these patients. Then, the Weinstein-Boriani-Biagini (WBB) staging system [18] was used as a guide to select the appropriate surgical approach and determine the scope of the operation.

Material and Methods

Clinical data

This study was approved by the Ethics Committee of our hospital. We performed a retrospective review of all 13 patients who were diagnosed with and treated for spinal osteoblastoma at our institution from June 2008 to November 2017. Nine males and 4 females were included, with a male to female ratio of 2.25. The ages at diagnosis varied from 9 to 70 years, with an average age of 32.9 years. The time from symptom onset to diagnosis of the disease ranged from 3 months to 15 months, with an average time of 8.6 months. Three tumors were located in the cervical spine, 1 tumor was located in the cervicothoracic junction, 4 tumors were located in the thoracic spine, 3 tumors were located in the lumbar spine, and 2 tumors were located in the sacral spine. The lesions were predominantly present in the posterior elements, such as the transverse processes, spinous processes, laminae and pedicles, with vertebral body involvement observed in 2 patients. According to the WBB staging system for primary spinal tumors, the tumors mainly involved the vertebral body areas and extended to 4 or 9 radiating zones in 2 cases, exhibited posterior element involvement from 10 to 3 radiating zones in 8 cases, and showed simple involvement of vertebral body areas from 4 to 9 radiating zones in 3 cases.

The diagnosis of osteoblastoma was established based on clinical data and imaging studies (Figures 1, 2) and confirmed by needle biopsy or open biopsy before surgery and pathological examination after surgery. Nine patients were diagnosed with computed tomography (CT)-guided biopsy, and 4 patients were diagnosed after open surgical resection. For each patient with spinal osteoblastoma, clinical data, including age, sex, the duration of symptoms preoperatively, nonsteroidal anti-inflammatory drug (NSAID) use before diagnosis, and pain, neurological deficits, and scoliosis at the time of diagnosis were recorded (Table 1). The main signs and symptoms observed in this study were as follows: 1) pain: all 13 patients with osteoblastoma experienced different scales of dull aching and localized pain. Generally, pain was the most common initial complaint, and 3 patients also suffered nocturnal pain. In addition, 7 patients required oral NSAIDs for pain relief. 2) Neurological deficits

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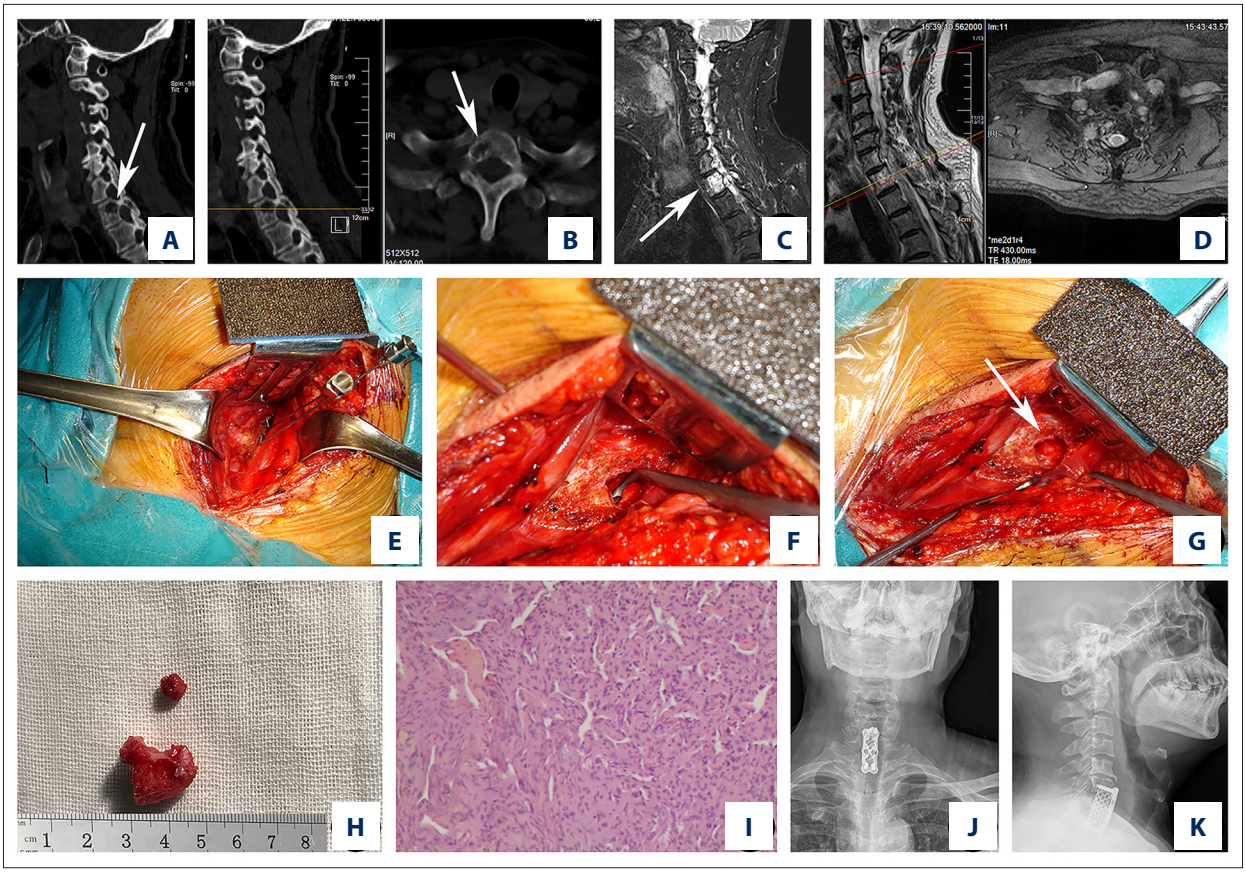

Figure 1. A case with T1 osteoblastoma localized in the right vertebral body and pedicle. Preoperative sagittal (**A**) and axial (**B**) CT scans demonstrate an expansile lesion with peripheral hardening of bony destruction of right vertebral body (white arrow). Preoperative (**C**) sagittal short time inversion recovery (STIR) sequence image and (**D**) sagittal-axial T2-weighted image showing that the paraspinal soft tissue mass exhibited high signal intensity with the T2WI and STIR sequences, indicating spinal cord compression (white arrow). (**E**) Intraoperative photo showing that the localization of lesion was performed. (**F, G**) Intraoperative photo showing that the tumor was completely removed (white arrow). (**H**) Intraoperative removal of specimens. (**I**) Photomicrograph of the specimen revealing a dense osteoid matrix and plump osteoblasts with new osteoid, suggesting osteoblastoma (hematoxylin and eosin, original magnification 100×). (**J, K**) Lateral radiographs of the cervical vertebrae at the 43-month follow-up showing C7–T2 stabilization without tumor recurrence.

were: 6 patients gradually developed nerve root symptoms or spinal cord compression, including various degrees of sensory or motor deficits, 3 of whom presented with paraparesis before admission to our institution. No bladder or bowel involvement was observed. 3) Scoliosis occurred in only 1 patient who presented with thoraco-lumbar scoliosis. All patients underwent careful physical examination before surgery, and focal neurological signs were recorded. Plain radiology, CT, and magnetic resonance imaging (MRI) of the lesion were routinely performed on all patients (Figures 1A, 1B, 2A–2C). In all imaging examinations, we must emphasize the importance of thin-section CT scans, which can help clinicians identify the nidus and surrounding sclerotic changes and reveal calcification and mineralization of the nidus (Figures 1A, 1B, 2A–2C). Additionally, whole-body bone scintigraphy (ECT) and positron emission tomography/CT(PET-CT) can also be useful for identifying metastatic spinal tumors. For osteoblastoma of the cervical spine, magnetic resonance angiography (MRA) or digital subtraction angiography (DSA) can determine whether the vertebral artery is involved. In our study, preoperative MRA of the cervical arteries was performed in 2 patients.

Surgical methods

In general, surgery was performed under general anesthesia. Then, accurate localization of the lesion was performed with fluoroscopy during the operation. The same group of experienced orthopedic oncology surgeons at our institution completed all the surgeries in this study. The surgical approaches and spinal reconstruction methods were selected based on the general conditions of the patients, the surgeons' experience and preferences, the extent of tumor involvement, and the stage of the tumor as classified according to the WBB staging system for spine tumors (Figures 1D, 2F, 2G). The surgical procedures

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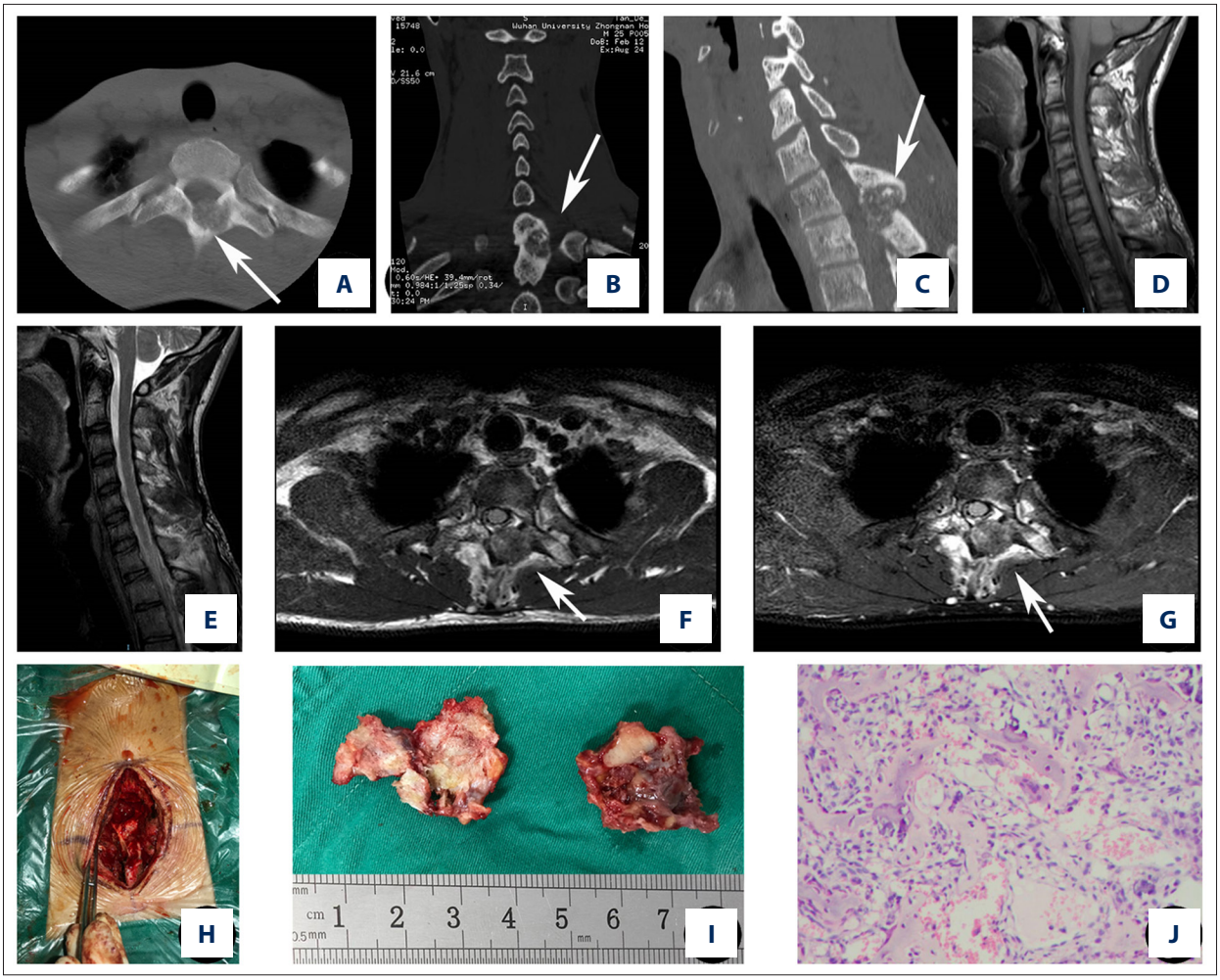

Figure 2. A case with T1 osteoblastoma localized in the left laminae. Preoperative axial (**A**), coronal (**B**) and sagittal (**C**) CT scans demonstrate an expansile lesion with peripheral hardening of bony destruction of left laminae (white arrow). Preoperative (**D**) sagittal T1-weighted image and (**E**) sagittal T2-weighted image showing that the paraspinal soft tissue mass exhibited high signal intensity with the T2WI and intermediate signal intensity with the T1WI sequence, indicating spinal cord compression. (**F**) Axial T2-weighted image and (**G**) axial STIR sequence image showing a single cystic lesion with cortical destruction at the posterior elements of the T1 vertebra and slight edema of the surrounding soft tissues. The lesion exhibited a hyperintense signal with the STIR sequence and a heterogeneously hypointense signal with the T2WI sequence (white arrow). (**H**) Intraoperative photo showing that the lesion was removed. (**I**) Intraoperative removal of specimens. (**J**) Postoperative pathological examination revealed that the stroma was composed of fibrovascular connective tissue. Plump osteoblasts with new osteoid and anastomosing trabeculae of woven bone suggesting osteoblastoma. (hematoxylin and eosin, original magnification 100×).

consisted of excision, including intralesional excision (curettage) or total excision. In addition to thorough decompression of the spinal cord and nerve roots, total excision of the involved posterior elements was performed (Figures 1E–1H, 2H, 2I). For cases with involvement of the vertebral body, intralesional excision (curettage) was performed to ensure maximal removal of the tumor and to minimize the risk of tumor recurrence (Figure 1F, 1G). Ten patients were subjected to tumor excision through a posterior approach, and 3 patients were treated with an anterior surgical approach. Reconstruction of the stability and structure of the spine was selectively performed based on the extent of lamina and vertebral body resection required, namely, whether the pedicle was removed and whether facet joint injury occurred. In 8 cases, we used posterior vertebral pedicle screws or anterior cervical titanium plate internal fixation after excision of the tumor (Figure 1J, 1K), and in 5 cases, no reconstruction was necessary. Five patients underwent implantation of autologous iliac bone grafts for spinal fusion. The incision was closed after repeated washing with pulse irrigation. Surgical characteristics were also recorded, including pathological results, Enneking stage (benign), WBB staging, postoperative complications, and whether fusion was performed (Table 2).

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Table 1. General information and preoperative characteristics of patients with spinal osteoblastoma.

Patient no.	Age at Diagnosis (years)	Sex	Duration of symptoms preoperatively (months)	Site of the lesion	Pain at diagnosis	Use of NSAIDs	Scoliosis at diagnosis	Symptoms of neurological deficits at diagnosis
1	26	Male	8	The right pedicle and vertebral body of S1	Yes	No	No	No
2	43	Male	3	The left laminae of T1	Yes	No	No	Yes
3	9	Female	9	The left pedicle and lamina of C3	Yes	Yes	No	No
4	70	Male	6	The vertebral body of C7 and T1	Yes	No	No	Yes
5	30	Male	10	The spinous process of L2	Yes	Yes	No	No
6	15	Female	15	The left transverse process of T11	Yes	No	Yes	Yes
7	27	Male	7	The right laminae of L4	Yes	Yes	No	No
8	33	Female	13	The left laminae of C6	Yes	No	No	Yes
9	40	Male	7	The vertebral body of C3	Yes	Yes	No	No
10	30	Male	10	The left pedicle of T10	Yes	Yes	No	Yes
11	38	Male	11	The spinous process of L2	Yes	No	No	No
12	45	Female	6	The left vertebral body of S1	Yes	Yes	No	No
13	22	Male	7	The right vertebral body and pedicle of T1	Yes	Yes	No	Yes

Symptoms of neurological deficits: 1 – symptoms of nerve root compression; 2 – bowel, bladder, and sexual dysfunction; and left plantar flexion weakness (3/5 strength); NSAIDs – nonsteroidal anti-inflammatory drugs.

Postoperative procedure and follow-up

The drainage tube was removed when the drainage flow was less than 50 mL per day. The patients were permitted to move approximately 2–3 weeks after surgery, but the spine was immobilized with an orthosis for 3 months until bony fusion was achieved. Follow-up examinations were performed every 3 months for the first year, every 6 months for the second year, and then annually. Examinations including standard radiographs, MRI, and CT of the affected segments performed at follow-up visits, and recovery of neurologic status, tumor recurrence, and the success of bone graft fusion were also assessed. Spinal fusion was characterized by bone trabeculae formation between the bone graft and adjacent spinal elements and substantial graft thickness on dynamic plain radiographs. Clinical outcomes were assessed preoperatively and at the last follow-up visit using the VAS score, ASIA impairment scale, and ODI score.

Statistics analysis

Statistical analysis was performed using SPSS software (SPSS, Inc., Chicago, IL, USA), and a paired *t*-test was adopted to compare preoperative and final follow-up VAS and ODI scores with a significance level of 0.05 (*P* value).

Results

General results

In this study, a total of 13 patients were identified, with an average follow-up duration of 43.8 months (range, 23–82 months). All the postoperative pathology diagnoses were osteoblastoma (Figures 1I, 2J). No intraoperative complications were noted, including worsening of the spinal cord or nerve root injury,

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Table 2. Tumor characteristics and surgical strategies.

Patient no.	Pathology	Enneking stage (benign)	WBB classification	Surgical treatment	Complication
1	Osteoblastoma	II	8, 9, 10, 11 B–D	Posterior partial sacrectomy, spinal fusion, allograft fusion and instrumentation from L5–S2	Incisional fat liquefaction
2	Osteoblastoma	II	1, 2, 3 B–D	Posterior laminectomy, spinal decompression and instrumentation from C7–T2	None
3	Osteoblastoma	II	2, 3, 4, 5 B–C	Posterior laminectomy, spinal decompression, autograft fusion and instrumentation from C2–C4	None
4	Aggressive osteoblastoma	III	5, 6, 7, 8, 9 A–C	Anterior hemi–vertebrectomy, spinal decompression combined with titanium mesh, autograft fusion and titanium plate internal fixation from C6–T2	Superficial infection
5	Osteoblastoma	II	12, 1 B–C	Posterior L2 tumor aggressive resection curettage without instrumentation	None
6	Osteoblastoma	II	1, 2, 3 B–D	Posterior laminectomy, spinal decompression and instrumentation from T9–L2	None
7	Osteoblastoma	II	9, 10 A–B	Posterior L4 tumor aggressive resection curettage without instrumentation	None
8	Osteoblastoma	II	1, 2, 3 B–D	Posterior laminectomy, spinal decompression and instrumentation from C5–C7	None
9	Osteoblastoma	II	5, 6, 7 B–C	Anterior C3 tumor aggressive curettage combined with high–speed burring, titanium plate internal fixation from C2–C4	None
10	Osteoblastoma	II	2, 3 A–B	Posterior T10 tumor aggressive curettage combined with high–speed burring, autograft fusion with instrumentation from T9–T11	None
11	Osteoblastoma, secondary aneurysmal bone cyst	II	12,1 B–D	Posterior L2 tumor aggressive resection curettage without instrumentation	None
12	Osteoblastoma	II	4, 5 B–C	Posterior S1 tumor aggressive curettage combined with high–speed burring and autograft without instrumentation	None
13	Osteoblastoma	II	8, 9, 10 B–D	Anterior T1 tumor aggressive curettage combined with high–speed burring, titanium plate internal fixation from C7–T2	None

WBB – Weinstein-Boriani-Biagini.

vertebral artery damage or tearing of the spinal dura matter. Postoperatively, the incision healed by first intention in all but 2 patients who had second intention healing due to superficial infection and fat liquefaction. No patients received postoperative chemotherapy or radiation after the initial surgery.

Blood loss and operative duration

The operative duration ranged between 100–230 minutes (average, 178.1 minutes). The intraoperative bleeding volume ranged between 230–1100 mL (average, 574 mL). And 4 patients required blood transfusions during the hospitalization. The mean hospital length of stay was 10.4 days (range, 7–21 days).

Imaging findings

We found that 61.5% (8 out of 13) of the tumors were truly confined to the posterior elements corresponding to WBB sectors 1–4 and 9–12, 23.1% (3 out of 13) of the tumors were found solely in the anterior part of the vertebral body

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Table 3. Preoperative information and final follow-up data regarding surgical efficacy according to VAS Score, ASIA Classification and ODI Score.

Patient no.	VAS score		ASIA grade		ODI score		Follow-up (months)	Recurrence
	Pre	Pos	Pre	Pos	Pre	Pos		
1	6	0	E	E	58	24	40	No
2	5	1	D	E	48	20	34	No
3	3	0	E	E	40	28	41	No
4	8	1	D	E	50	24	59	Yes
5	6	0	E	E	48	20	28	No
6	6	0	C	E	62	30	23	No
7	9	0	E	E	52	20	30	No
8	4	1	C	E	66	30	30	No
9	8	2	E	E	42	16	33	No
10	5	0	C	E	56	16	36	No
11	7	1	E	E	44	18	78	No
12	6	0	E	E	46	22	56	No
13	8	1	D	E	52	26	82	No

Pre – preoperatively; Pos – postoperatively; VAS – Visual analog scale, ASIA – American Spinal Injury Association, ODI – Oswestry Disability Index.

corresponding to WBB sectors 5–8, and 15.4% (2 out of 13) of the tumors extended to both the anterior and posterior elements. All the postoperative pathology diagnoses were osteoblastoma. Graft union was identified within 3 to 6 months after surgery, with an average of 5 months. During the follow-up period, local recurrence occurred only in 1 patient, and en bloc marginal resection with postoperative radiotherapy was performed. Additionally, no recurrence of the tumors or loosening, migration or rupture of the bone grafts was discovered in the remaining patients at the final follow-up (Figure 1J, 1K).

Neurological status and VAS score

During the follow-up period, VAS scores decreased from 6.2±1.7 to 0.5±0.7 (P<0.001). The ASIA classification was as follows: 3 cases of grade C disease, 3 cases of grade D disease, 7 cases of grade E disease, 1 case of grade D disease (3 months postoperatively), and 10 cases of grade E disease (3 months postoperatively). All patient ASIA scores had improved to grade E at the final follow-up (Table 3). The mean ODI score improved from 51.1±7.7 before surgery to 22.6±4.9 at the last visit, reflecting a significant decrease (P<0.001). All patients remained neurologically stable without any major complications.

Discussion

Clinical features and location

Clinically, osteoblastoma is classified by the World Health Organization (WHO) as a typically osteoblastic, benign but locally aggressive tumor [14]. Osteoblastomas occur most frequently in children between 10 and 15 years of age [7,8]. The main symptoms of patients with spinal osteoblastoma often include persistent localized pain in the neck or back, paravertebral muscular spasm, and stiffness, and the pain is characterized as a dull ache that is less severe at night than during the day. However, these symptoms tend to be associated with a lack of robust response to medications, such as NSAIDs and aspirin [11,19,20]. Because of the rarity or the nonspecific symptoms of spinal osteoblastoma, these lesions are seldom diagnosed at the beginning of the course of disease but rather during the later stages. Furthermore, osteoblastoma can cause pronounced bone destruction, soft tissue infiltration, and epidural extension and is not easy to treat surgically [21]. In addition, neurological deficits such as paraparesis and paraplegia occur in almost one-third of patients, and radicular symptoms may also occur in as many as 50% of patients due to either pathological fractures or soft tissue extension producing a mass effect [1,6,22,23]. Recently, Boriani et al. [22] reported a series in which 75% of patients had spinal cord compression

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and 50% presented with scoliosis induced by muscular spasm secondary to an inflammatory effect around the tumor. This finding was also reported by Zileli et al. [6], and the results of their study showed that neurological deficits occurred in 69% of all patients. Notably, according to the anatomical location of the tumor, the specific clinical symptoms and neurological signs may vary. As described by Raskas et al. [2], patients with cervical osteoblastoma may have a high incidence of torticollis, probably due to increased involvement of the soft tissues in the epidural space. Other location-specific presentations, including thoracic myelopathy or lumbosacral radiculopathy, are consistent with data obtained in the study by Lucas et al. [5]. Sacral osteoblastomas have been shown to present with abdominal manifestations [11,24–26]. Additionally, Nemoto et al. [27] reviewed 75 spinal osteoblastoma cases and found equal frequencies of these tumors in the cervical, thoracic, and lumbar spine.

According to our results, more than half of the patients with osteoblastoma were younger than 30 years, and the mean age was 32.9 years. The male to female ratio was 2.25: 1. We found that 61.5% (8 out of 13) of the tumors were truly confined to the posterior elements corresponding to WBB sectors 1–4 and 9–12, 23.1% (3 out of 13) of the tumors were found solely in the anterior part of the vertebral body corresponding to WBB sectors 5–8, and 15.4% (2 out of 13) of the tumors extended to both the anterior and posterior elements. However, no difference was found in the incidence of osteoblastoma in the cervical spine, thoracic spine and lumbar spine. Our patients' symptoms, which were nonspecific, persisted for approximately 8.6 months and did not improve despite treatment with NSAIDs. The osteoblastoma sites and the mean age of the patients in this study were consistent with those reported in previous studies [3–5,12,27].

Diagnosis and radiographic presentation

Because of the unique features and complexity of the spinal column, orthopedic surgeons and radiologists cannot detect tiny lesions and determine an early diagnosis. Osteoblastoma generally arises within the posterior spinal elements, and the radiological presentation of these lesions can vary [28]. In our daily clinical practice, plain radiography is the most common radiological examination choice and is thought to have high value for diagnosing spinal osteoblastoma. The characteristic appearance of osteoblastoma on radiographs is a dense shell of bone surrounding the lesion, with some tumors resembling osteoid osteoma with a radiolucent nidus and surrounding sclerotic changes. Furthermore, in some cases, the bony shell tends to be very thin, with expansion into adjacent soft issues [11,14]. As reported by Lucas et al. [5], cortical expansion and destruction were common radiographic findings, and 12% of cases had features suggestive of malignancy. In a single-center study of 32 patients with osteoblastoma in the mobile spine, Yin et al. [21] concluded that normal images were found in half of the patients with osteoblastoma, which may result in a high number of misdiagnoses if radiography is used as the only diagnostic tool. Therefore, the authors believe that plain radiography is not a reliable method and can lead to misdiagnosis of osteoblastoma in the spine.

According to various studies and clinical observations, a CT scan is important for revealing calcification and mineralization of the nidus and the extent of bone destruction, which can facilitate preoperative planning for surgery [23]. Therefore, most scholars believe that a CT scan is a better radiological choice than plain radiography for diagnosis. Typically, the characteristic CT appearance of spinal osteoblastoma is a lytic expansile lesion with a shell of sclerosis, and soft tissue masses can be observed around the lesion (Figure 2A–2C). In addition, CT is superior to MRI for demonstrating the scattered or extensive foci of calcification or ossification in some lesions [29]. Similarly, Ozkal et al. [28] reported that CT was superior to MRI in demonstrating matrix ossification surrounding the bony shell. In a recent systematic review, Harrop et al. [10] concluded that the gold standard radiologic technique is CT because this modality can be used to measure the extent of bony destruction and the degree of sclerosis. However, MRI is particularly valuable for displaying spinal cord compression injuries, which is important for selecting a treatment method and defining a prognosis [11,30]. The imaging features of spinal osteoblastoma on MRI are considered nonspecific. These lesions often display a low to isointense signal on T1-weighted MRI, whereas T2-weighted MRI demonstrates an intermediate- to high-intensity signal due to matrix calcification and intense enhancement representing the highly vascular nature of such lesions (Figures 1C, 1D, 2D–2G). Notably, however, this radiographic appearance may lead to overestimation of the limits of the tumor and can be somewhat confusing to orthopedic surgeons and radiologists, who may interpret these tumors as other clinical entities such as Ewing's sarcoma or lymphoma [7,10,31]. For instance, a "flare phenomenon" was described by Crim et al. [32] in 1990. Specifically, these neoplasms often cause a diffuse, reactive prostaglandin (PG) – mediated inflammatory infiltrate within adjacent vertebrae surrounding paraspinal soft tissues. In contrast, for aggressive osteoblastoma in the spine, the tumor may be an expansile lesion with a multitude of small calcifications, a prominently sclerotic rim, and paravertebral and epidural extensions and may also radiographically mimic aneurysmal bone cysts, osteosarcomas, or bone metastases [7,25]. Another essential diagnostic tool is bone scintigraphy, which is the most sensitive radiographic scan described in the literature for osteoblastoma and typically shows increased radiotracer uptake, indicating increased osseous turnover [11]. Finally, the gold standard for definitive diagnosis is pathological examination. Histologically, osteoblastoma is characterized by

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the presence of plump and epithelioid osteoblasts producing woven bone that displays both osteoblastic and osteolytic characteristics [1]. However, aggressive osteoblastomas tend to be more immature and display prominent nucleoli, larger trabeculae, and invasion of cortical bone, with a tendency to exhibit osteoclast-like cells more frequently. Notably, preoperative alkaline phosphatase may be a screening tool to facilitate differentiation of aggressive versus conventional osteoblastomas [10,11,13,14]. As reported by Yin et al. [21], preoperative alkaline phosphatase was significantly higher in aggressive osteoblastomas than that in conventional osteoblastomas ($P<0.0005$). Furthermore, they also found a significant decrease in alkaline phosphatase after surgery. In our series, all patients underwent standard radiography, CT and MRI before diagnosis (Figures 1A–1D, 2A–2G). We acknowledge that clinical experience and imaging information are both important in reducing missed lesions and determining a definite diagnosis, especially on CT scans. When we could not exclude the possibility of malignant transformation or even the possibility of a metastatic spinal tumor, lymphoma or aneurysmal bone cyst, CT-guided biopsy of the soft tissue and the osseous lesion was routinely performed by experienced orthopedic oncology surgeons at our institution.

Surgical treatment

In the literature, the role of radiation therapy in the management of osteoblastoma is controversial, and open surgery remains the mainstay treatment for this lesion [1,27]. Several previous studies have demonstrated that aggressive surgical resection can yield the best overall outcomes in patients with osteoblastoma and is also the most important prognostic factor for local recurrence [1,3,6,12,22,33]. Some scholars believe that total en bloc resection is a good option when possible [19,22,34]. However, according to our experience, complete resection is not possible in certain locations, such as the spine, because of anatomic constraints, tumor volume, an unacceptable risk of morbidity, and loss of function. The surgical indications for spinal osteoblastoma consist of persistent pain, increasing tumor size, neurological deficits, and potential for malignant transformation and bony destruction due to aggressive behavior that may destroy neighboring spinal stability and neurovascular structures [25,26,30].

Currently, the most widely accepted assessment system for primary musculoskeletal tumors is the Enneking classification, which is used to determine treatment and evaluate prognosis. According to the Enneking system, stage 2 lesions are considered active lesions, and stage 3 lesions are considered benign aggressive lesions [35]. In a comprehensive systematic review, Harrop et al. [10] analyzed reported primary osteoblastomas and found only 17 relevant case reports. According to a comparison of the aggressive features of osteoblastoma, the recurrence rate after subtotal resection was only 10% to 15% for stage 2 lesions and up to 50% for stage 3 lesions. Based on this limited evidence, they strongly recommended extensive intralesional excision (curettage) for nonaggressive, Enneking stage 1 and 2 osteoblastomas. In addition, for stage 3 lesions, wide resection was recommended to ensure removal of all tumor – bearing tissue. In 2012, Boriani et al. [22] reported 51 cases of osteoblastoma in the mobile spine and assessed the role of the Enneking staging system in selecting the best treatment for patients with different stages of osteoblastomas of the spine. They found no local recurrence in patients with stage 2 disease treated with aggressive excision (curettage), and only 2 patients (15.4%) treated with en bloc resection exhibited local recurrence. However, because of the complexity and the low incidence of primary spinal tumors, the Enneking staging system cannot fully account for certain features and limitations, such as involvement of the epidural compartment and neurological structures or the need to restore spinal stability. Therefore, we combined the Enneking classification system with the WBB surgical staging system [18], which considers the complex anatomy of the spine, to guide the surgical management of the lesions. However, the largest multicenter study of a cohort of patients with spinal osteoblastomas aiming to determine whether the use of the Enneking classification system in the management of spinal osteoblastomas influenced local recurrence and survival time was recently reported by Versteeg et al. [33]. They found that application of the Enneking classification system as a treatment guide for spinal osteoblastoma to prevent local recurrence was not validated. However, most studies have indicated that the Enneking system can be regarded as an excellent guide for selecting the appropriate treatment for spinal osteoblastoma [13,14,21,22,26,30,36].

Based on our surgeons' clinical experience, one patient with an aggressive variant of an Enneking stage 3 tumor was treated with marginal en bloc resection, while the remaining Enneking stage 1 and stage 2 patients were treated with aggressive excision (curettage). High-speed burring may be used to remove the tumor and the margins around it, resulting in curative resection [20]. Several precautions considered when performing surgery for spinal osteoblastoma. First, the most important factor for achieving complete resection is an exact evaluation. Preoperative imaging examinations, such as MRI and CT, can show whether the lesion extends into the paraspinal space, which may impede complete resection. Second, larger lesions often require more extensive resection, which may destabilize the spine. Therefore, when resection involves extended areas of the intervertebral articulations or pedicles, instrumented stabilization and fusion are warranted to ensure long-term stability and to prevent progressive deformity in the future. Additionally, continuous long-term follow-ups are required to observe the stability of the spine. Third, because osteoblastoma is a hypervascularized tumor, preoperative embolization of the

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feeding vessels may be necessary and can reduce bleeding during surgery and facilitate total resection. Fourth, for the treatment of stage 3 osteoblastoma, a more aggressive strategy should be selected. En bloc resection with wide surgical margins should be the first treatment option. Finally, meticulous surgical techniques, including high-speed burring, also constitute an important step in reducing recurrence rates in patients with spinal osteoblastoma.

The main limitations of our study were its retrospective design and the inclusion of only 13 patients who were treated over a short period, which did not allow determination of statistical significance. The duration of the follow-up was long. The minimum follow-up time was 23 months, while the maximum follow-up time was 82 months. In addition, more patients should be recruited to better understand the treatment choices for this lesion. However, despite following general guidelines, minor differences in surgical techniques may have occurred. Our findings may provide a possible basis for a multicenter prospective study in the future to determine the best treatment protocol for osteoblastoma localized in the spine.

Conclusions

In conclusion, osteoblastoma is a rare benign tumor with a predilection for the posterior elements of the spine column. Treatment experiences are limited. Diagnosis and treatment of this lesion involve multimodality radiological imaging and careful histological and surgical evaluations to determine the best treatment protocol. Aggressive surgical resection for patients with spinal osteoblastomas can achieve satisfactory clinical and radiographic outcomes and is worthy of recommendation.

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Conflict of interests

None.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Zhongnan Hospital of Wuhan University.

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