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# Intraoperative vertebroplasty during surgical decompression and instrumentation for aggressive vertebral hemangiomas: A retrospective study of 39 patients and review of the literature

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Keywords: Aggressive Vertebral Hemangioma; Decompression Surgery; Intraoperative Vertebroplasty; Blood loss; Enneking Stage; Surgical Management.

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**Abstract**

**Background Context:** Aggressive (Enneking Stage 3, S3) vertebral hemangiomas (VHs) are rare, which might require surgery. However, the choice of surgery for S3 VHs remains controversial because of the rarity of these lesions.

**Purpose:** We reported our experience of treating S3 VHs, and evaluated the effectiveness and safety of intraoperative vertebroplasty during decompression surgery for S3 VHs.

**Study Design:** This is a retrospective study.

**Patient Sample:** Thirty-nine patients with a definitive pathological diagnosis of aggressive VHs who underwent primary decompression surgery in our department were included in this study.

**Outcome Measures:** Basic data such as surgical procedure, surgical duration, estimated blood loss during surgery, pathology were collected. The modified Frankel grade was used to evaluate neurological function. Enneking staging was based on radiological findings.

**Methods:** We retrospectively examined aggressive VHs with neurological deficits. Surgery was indicated if the neurological deficit was severe or developed quickly or if radiotherapy was ineffective. Decompression surgery was performed. Intraoperative vertebroplasty during posterior decompression has been used since 2009. If contrast-enhanced CT revealed a residual lesion, we recommended adjuvant

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radiotherapy with 40–50 Gy to prevent recurrence. Patients' basic and surgical information was collected. The minimum follow-up duration was 18 months. This study was partially funded by XXXXXX (Blinded).

**Results:** Average age of the 39 patients with S3 VHs who underwent primary decompression surgery was 46.2 (range, 10–69) years. All patients had neurological deficits caused by aggressive VHs. Aggressive VH lesions were located in the cervical, thoracic, and lumbar spine in two, 32, and five patients, respectively. The decompression-alone group had 17 patients and the decompression plus intraoperative vertebroplasty groups had 22. There were no statistically significant intergroup differences in preoperative information ($P > 0.05$). The average estimated blood losses were 1764.7 mL (range, 500–4000 mL) and 1068.2 mL (range, 300–3000 mL) in the decompression-alone and decompression plus vertebroplasty group, respectively ($P = 0.017$). One patient who underwent primary decompression alone without adjuvant radiotherapy experienced recurrence after the first decompression. The average follow-up was 50.2 (range, 18–134) months, and no cases of recurrence were observed at the last follow-up.

**Conclusions:** Our results suggest that posterior decompression effectively provides symptom relief in patients with aggressive (S3) VHs with severe spinal cord compression. Intraoperative vertebroplasty is a safe and effective method for minimizing blood loss during surgery, while adjuvant radiotherapy and/or vertebroplasty help in minimizing recurrence after decompression.

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## Introduction

Hemangiomas, which present as benign tumors comprising newly formed blood vessels, are a type of vascular malformation [1]. Vertebral hemangiomas (VHs) are the most common benign tumors involving the spinal column and frequently affect the thoracic spine. The incidence of VHs is 10%–26%; most cases are asymptomatic (Enneking stage 1[2], S1), with only 0.9%–1.2% symptomatic cases [1, 3-6]. Approximately 55% symptomatic VHs present with pain as the only symptom (Enneking stage 2, S2). The other 45% are aggressive, with possible invasion of the spinal canal and/or paravertebral space, which leads to neurological deficits (Enneking stage 3, S3) [3, 6-13].

Asymptomatic VHs (S1) are generally found incidentally and require only observation, whereas S3 VHs might require surgery. However, the choice of surgery for S3 VHs remains controversial because of the rarity of these lesions. Decompression with laminectomy and debulking is relatively less technically demanding [3-5, 11, 14]. Japanese surgeons have reported total en bloc spondylectomy to achieve wide oncological margins [9]. Acosta et al. and Goldstein et al. recommended intralesional vertebrectomy because of the benign nature of these lesions [6, 10]. Moreover, Doppman et al. suggested direct intralesional injection of ethanol [15]. VHs are highly vascular lesions and can cause intraoperative excessive





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hemorrhage during surgery. Preoperative embolization is often mandatory to minimize blood loss [9-11, 16].

At our institution, we performed intraoperative vertebroplasty for external embolization and learned that it can effectively minimize blood loss. In the present study, we retrospectively evaluated the effectiveness and safety of vertebroplasty during decompression surgery for S3 VHs.

## Materials and methods

### *General information*

This study was approved by our hospital's ethics committee and conducted according to the principles of the Declaration of Helsinki.

We reviewed our spinal tumor database and identified a total of 61 patients with aggressive (S3) VHs who had undergone treatment or consultation with the spinal surgery team at our hospital between 2001 and 2016. Patients treated before 2001 were lost to follow-up because of frequent changes in addresses and telephone numbers. Eventually, we identified 39 patients with a definitive pathological diagnosis of aggressive VHs who underwent primary decompression surgery in our department.

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Hospital charts, operating room reports, anesthesia reports, office charts, pathology reports, and radiographs of the included patients were retrospectively evaluated. Data pertaining to patient age, sex, symptoms, underlying diseases, smoking habits, body mass index (BMI), neurological function, radiological features, Enneking stage, surgical procedure, surgical duration, estimated blood loss during surgery, pathology, time between surgery and discharge, and treatment complications were collected. The modified Frankel grade was used to evaluate neurological function. Enneking staging was based on radiological findings.

*Imaging and biopsy*

We routinely performed posteroanterior and lateral spinal radiography, computed tomography (CT), and magnetic resonance imaging (MRI) for all patients. Typical lesions exhibit a honeycomb appearance on CT and a salt-and-pepper appearance on MRI. For patients with atypical images, CT-guided biopsy was indicated and performed by our interventional radiologists.

*Treatment protocol*

In our practice, radiotherapy is generally the first choice of treatment, particularly for patients with mild or slowly developing neurological deficits, including those with





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multiple-level VHs and/or massive soft tissue invasion. Indications for surgery at our institute include ineffective radiotherapy and/or severe or rapidly developing neurological deficits (muscle strength grade of <3/5 and rapid deterioration of neurological function within 2 weeks).

Four experienced surgeons performed all decompression surgeries, and the surgical techniques were chosen according to each surgeon's personal preference. Two surgeons began performing vertebroplasty during posterior decompression since 2009, while the other two used the conventional decompression procedure.

*Surgical techniques*

Posterior decompression was performed in the prone position under general anesthesia. After the pedicle screws were in place, the adjacent cranial and caudal laminae were removed for direct visualization of the normal dural sac. Bilateral transpedicular cement (normal viscosity) was injected with slight pressure to shrink the vessels in the affected vertebral body (VB). Under fluoroscopic guidance, the tip of the cannula was inserted at the ventral edge of the lesion to fill the affected VB with as much cement as possible. The volume of the epidural tumor may decrease after cement filling because of the decreased blood supply. Direct visualization of the adjacent dural sac and the decreased blood loss permitted the safe performance of laminectomy through the affected lesion. The interior pedicles were removed using a



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burr. Before resection, the epidural tumor could be further decreased in size using bipolar coagulation; this resulted in the achievement of ideal decompression. Further bony curettage of VB was generally not necessary, with the exception of patients exhibiting obvious bony compression. After instrumentation, allograft was used to achieve posterolateral fusion.

*Follow-up*

We obtained roentgenograms at 3, 6, and 12 months after the index procedure and annually thereafter. At the 3-month follow-up, if contrast-enhanced CT revealed a residual lesion, we recommended adjuvant radiotherapy with 40–50 Gy to prevent recurrence. MRI was performed at the 3-month follow-up and annually thereafter. If the patient displayed symptoms indicative of local recurrence, immediate MRI was indicated. The minimum follow-up duration was 18 months.

To evaluate the cement filling rate after surgery with intraoperative vertebroplasty, the maximum area of bone cement and the lesions were measured on axial CT images obtained after surgery. AutoCAD 2014 software (AUTODESK Inc., San Rafael, CA, USA) was used to calculate the area. (Figures 1-H, 2-G, and 3-J)

*Statistical analysis*

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SPSS version 18.0 (SPSS Inc., Chicago, IL, USA) was used to analyze all collected data. The Kolmogorov–Smirnov test was used to identify whether the data were normally distributed. Measurable variables are presented as means and standard deviations if the data were normally distributed and median and maximum\minimum values if the data were not normally distributed. Student's t-test and the Mann–Whitney U test were used to compare differences in normally and abnormally distributed data, respectively. Immeasurable variables are presented as percentages, with the use of the chi-squared test or Fisher's exact test for comparisons. A P-value of 0.05 was considered statistically significant.

**Results**

There were 14 men and 25 women (including two pregnant women) in this study. The average age was 46.2 (range, 10–69) years at the time of diagnosis.

All patients exhibited neurological deficits caused by aggressive VHs. In total, 31 patients exhibited myelopathy (Frankel grade B, C, and D in four, four, and 23 patients, respectively). Four and three patients exhibited cauda equina syndrome and radiculopathy, respectively. Eighteen patients also complained of pain. The average time between symptom onset and surgery was 5.14 (range, 0.25–26) months.





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The aggressive VHs were located in the cervical, thoracic, and lumbar spine in two, 32, and five patients, respectively. Four patients had multiple lesions, although only one vertebra contained a symptomatic S3 lesion. In three patients, VHs were located only in VB. The lesions in the remaining patients involved the posterior arches, with 24 involving the bilateral pedicles and 12 involving a unilateral pedicle. All these lesions exhibited epidural extensions, while 13 patients exhibited paraspinal extensions. Neurological compression was caused by soft masses in 25 patients and a combination of soft and hard masses in 14 patients.

Twelve patients with atypical radiological findings underwent percutaneous CT-guided biopsy. A definitive pathological diagnosis could be established for only seven (58.3%) patients; the results were not diagnostic for the remaining five, including two with only connective tissue cells, two with only peripheral blood cells, and one with suspicious results that needed to be distinguished from those for malignant vessel tumors. Thirteen patients underwent preoperative embolization.

*Decompression alone vs. decompression with vertebroplasty*

In total, 17 patients underwent only decompression and 22 underwent decompression with vertebroplasty. There were no statistically significant intergroup differences in





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sex, age, BMI, underlying diseases, smoking habits, VH location, and the use of embolization ($P > 0.05$; Table 1).

In the decompression group, the average estimated blood loss was 1764.7 (range, 500–4000) mL. The average surgical duration was 270.0 (range, 180–420) min and the average time to discharge was 8.3 (range, 3–16) days after the index surgery. In the decompression with vertebroplasty group, the average estimated blood loss was 1068.2 (range, 300–3000) mL. The average surgical duration was 249.5 (range, 150–360) min and the average time to discharge was 7.0 (range, 4–12) days after the index surgery. There was a statistically significant intergroup difference in the estimated blood loss ($P = 0.017$; Table 2).

One dural sac tear was identified during surgery and successfully repaired. There were no severe intraoperative complications other than massive intraoperative bleeding. Eight and four patients in the decompression and decompression with vertebroplasty groups, respectively, underwent adjuvant radiotherapy after surgery. All lesions were pathologically confirmed as VHs after surgery.

*Follow-up and recurrence*

All patients were followed up. The average follow-up duration was 50.2 (range,





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18–134) months. All patients were symptom-free without any neurological deficits at the last follow-up visit. One of nine patients (11.1%) who underwent primary decompression alone without adjuvant radiotherapy experienced recurrence after the first decompression. This patient underwent a second decompression procedure with adjuvant radiotherapy and did not exhibit recurrence at 64 months after the revision surgery.

For the 22 patients who underwent decompression with vertebroplasty, the mean cement filling rate was 77.0% (range, 54.1%–93.8%), with no recurrence observed at the last follow-up; this included the 18 patients who did not receive radiotherapy, with a mean bone cement filling rate of 80.0% (range, 64.1%–93.8%).

**Discussion**

Since the vast majority of VHs are asymptomatic and found incidentally (Enneking stage 1, S1), they do not require treatment. However, aggressive VHs (Enneking stage 3, S3) may lead to spinal cord compression, vertebral bony destruction, and/or neurological deficits. Surgery is usually indicated for patients with severe neurological deficits and/or marked instability.

**Surgery.** Different surgical techniques, namely decompression surgery, intralesional vertebrectomy, and total en bloc spondylectomy, have demonstrated acceptable results

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(Table 3)[3, 4, 6, 8-10, 15, 17-19]. However, there is no consensus on the best treatment strategy for symptomatic VHs.

Vertebrectomy or en bloc resection for aggressive VHs are associated with low recurrence rates, although they are more technically demanding and accompanied by greater blood loss and higher morbidity [4, 9, 10]. Japanese surgeons (Tomita et al. [9] and Ogawa et al. [12]) reported that radical total en bloc spondylectomy for VHs was time consuming, often hemorrhagic, and quite technically demanding. In their cases, even after preoperative embolization, the estimated blood loss was 2420 (range, 1580–3400) mL and the surgical duration was 608 (range, 480–700) min. Vasudeva et al [18] stated that en bloc resection provided benefits similar to those of gross total resection or subtotal resection, although it was associated with higher morbidity rates. Acosta et al. [10] reported intralesional vertebrectomy, which was also associated with a low recurrence rate. However, in their cases (n = 10), the average blood loss after embolization was 2.1 (range, 0.8–5) L. In a multicenter study by Goldstein et al. [6], the rate of VH recurrence after intralesional vertebrectomy was 5.4% (2/37), with no recurrence after other procedures, including decompression (n = 17) and en bloc resection (n = 7). They concluded that formal en bloc resection is not required, and that excellent rates of local control and long-term survival can be achieved with aggressive intralesional resection during the index surgery.



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Decompression surgery is widely used because it is less technically demanding [3-5, 11, 14]. Combined with spinal fixation, decompression is reliable for achieving neurological recovery and spinal stability, while vertebroplasty and/or radiotherapy is mandatory to prevent local recurrence [3-6, 11, 14].

**Intraoperative Vertebroplasty.** VHs are highly vascular lesions that can result in significant intraoperative hemorrhage. Preoperative embolization can decrease this blood loss [14]. In the present study, intraoperative vertebroplasty decreased blood loss through the injection of bone cement into VB, which could obliterate and shrink the vessels in VHs. To our knowledge, the technique of intraoperative vertebroplasty with bone cement has only been reported in small case series [18, 20]. Similarly, Singh et al. [17] reported that intraoperative alcohol injection into VB achieved ideal blood loss control. However, the injection of alcohol is associated with a higher risk of complications such as Brown–Sequard syndrome and pathological fracture [15, 21, 22].

To avoid recurrence, complete obliteration of the lesion with bone cement is indicated. Of the 22 patients treated with decompression plus vertebroplasty in our study, 18 with a relatively higher bone cement filling rate did not receive radiotherapy after surgery and did not exhibit any recurrence.

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**Radiotherapy.** Radiotherapy is also widely used for the treatment of VHs [13, 23, 24]. Fractionated doses under 40 Gy spread out over a 3- to 4-week period are associated with minimal risk. Heyd et al. [24]from Germany reported radiotherapy treatment for 84 patients with VHs. Fox and Onofrio [3] showed that 50% (3/6) patients experienced recurrence of neurological deficits after subtotal tumor removal plus radiotherapy with ≤10 Gy (average time to recurrence was 9.3 years). However, no recurrence was observed in patients who underwent subtotal tumor removal plus radiotherapy with 26–40 Gy or gross total tumor excision. The most severe complication of radiotherapy is the malignant transformation of VHs and nearby tissues[24-26]. However, the cancer risks of radiotherapy are extremely low. In our study, there was no malignant transformation due to radiotherapy.

*Limitations*

The major limitations of our study include its retrospective design and the inclusion of data from a single center. In addition, there may be some bias during our data analysis. Future prospective multicenter studies are needed to verify our results.

*Financial associations*

This study was partially funded by XXXXXX (Blinded).

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## Conclusions

In conclusion, our results suggest that posterior decompression effectively provides symptom relief in patients with aggressive (S3) VHs with severe spinal cord compression. Intraoperative vertebroplasty is a safe and effective method for minimizing blood loss during surgery, while adjuvant radiotherapy and/or vertebroplasty help in minimizing recurrence after decompression.

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## Reference

1. 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. European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society. 2015;24(10):2189-95.
2. Enneking WF. A system of staging musculoskeletal neoplasms. Clin Orthop Relat Res. 1986;(204):9-24.
3. Fox MW, Onofrio BM. The natural history and management of symptomatic and asymptomatic vertebral hemangiomas. Journal of neurosurgery. 1993;78(1):36-45.
4. Pastushyn AI, Slin'ko EI, Mirzoyeva GM. Vertebral hemangiomas: diagnosis, management, natural history and clinicopathological correlates in 86 patients. Surgical neurology. 1998;50(6):535-47.
5. Jiang L, Liu XG, Yuan HS, et al. Diagnosis and treatment of vertebral hemangiomas with neurologic deficit: a report of 29 cases and literature review. Spine J. 2014;14(6):944-54.
6. Goldstein CL, Varga PP, Gokaslan ZL, et al. Spinal hemangiomas: results of surgical management for local recurrence and mortality in a multicenter study. Spine. 2015;40(9):656-64.
7. Lee S, Hadlow AT. Extraosseous extension of vertebral hemangioma, a rare cause of spinal cord compression. Spine. 1999;24(20):2111-4.
8. Acosta FL, Jr., Sanai N, Chi JH, et al. Comprehensive management of symptomatic and aggressive vertebral hemangiomas. Neurosurg Clin N Am. 2008;19(1):17-29.
9. Kato S, Kawahara N, Murakami H, et al. Surgical management of aggressive vertebral hemangiomas causing spinal cord compression: long-term clinical follow-up of five cases. J Orthop Sci. 2010;15(3):350-6.
10. Acosta FL, Jr., Sanai N, Cloyd J, Deviren V, Chou D, Ames CP. Treatment of Enneking stage 3 aggressive vertebral hemangiomas with intralesional spondylectomy: report of 10 cases and review of the literature. Journal of spinal disorders & techniques. 2011;24(4):268-75.
11. Blecher R, Smorgick Y, Anekstein Y, Peer A, Mirovsky Y. Management of symptomatic vertebral hemangioma: follow-up of 6 patients. Journal of spinal disorders & techniques. 2011;24(3):196-201.
12. Ogawa R, Hikata T, Mikami S, et al. Total en bloc spondylectomy for locally aggressive vertebral hemangioma causing neurological deficits. Case reports in orthopedics. 2015;2015:724364.
13. Sewell MD, Dbeis R, Bliss P, Watkinson T, Hutton M. Radiotherapy for

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acute, high-grade spinal cord compression caused by vertebral hemangioma. Spine J. 2016;16(3):e195-6.

14. Templin CR, Stambough JB, Stambough JL. Acute spinal cord compression caused by vertebral hemangioma. Spine J. 2004;4(5):595-600.

15. Doppman JL, Oldfield EH, Heiss JD. Symptomatic vertebral hemangiomas: treatment by means of direct intralesional injection of ethanol. Radiology. 2000;214(2):341-8.

16. Robinson Y, Sheta R, Salci K, Willander J. Blood Loss in Surgery for Aggressive Vertebral Haemangioma with and without Embolisation. Asian Spine J. 2015;9(3):483-91.

17. Singh P, Mishra NK, Dash HH, et al. Treatment of vertebral hemangiomas with absolute alcohol (ethanol) embolization, cord decompression, and single level instrumentation: a pilot study. Neurosurgery. 2011;68(1):78-84; discussion

18. Vasudeva VS, Chi JH, Groff MW. Surgical treatment of aggressive vertebral hemangiomas. Neurosurgical focus. 2016;41(2):E7.

19. Song RX, Zhang YG, Zhang XS, Zheng GQ, Wang Y. [One-stage total en bloc spondylectomy and reconstruction via a single posterior approach for thoracic vertebral symptomatic hemangioma associated with spinal cord dysfunction]. Zhonghua Wai Ke Za Zhi. 2012;50(4):342-5.

20. Zhang HL, Hu YC, Aryal R, He X, Lun DX, Zhao LM. Thoracic Vertebral Hemangioma with Spinal Cord Compression: Multidisciplinary Surgical Treatment and Follow-up of Six Patients. Orthop Surg. 2016;8(4):462-7.

21. Goyal M, Mishra NK, Sharma A, Gaikwad SB, Mohanty BK, Sharma S. Alcohol ablation of symptomatic vertebral hemangiomas. AJNR Am J Neuroradiol. 1999;20(6):1091-6.

22. Niemeyer T, McClellan J, Webb J, Jaspan T, Ramli N. Brown-Sequard syndrome after management of vertebral hemangioma with intralesional alcohol. A case report. Spine. 1999;24(17):1845-7.

23. Miszczyk L, Tukiendorf A. Radiotherapy of painful vertebral hemangiomas: the single center retrospective analysis of 137 cases. Int J Radiat Oncol Biol Phys. 2012;82(2):e173-80.

24. Heyd R, Seegenschmiedt MH, Rades D, et al. Radiotherapy for symptomatic vertebral hemangiomas: results of a multicenter study and literature review. Int J Radiat Oncol Biol Phys. 2010;77(1):217-25.

25. Beyzadeoglu M, Dirican B, Oysul K, Surenkok S, Pak Y. Evaluation of radiation carcinogenesis risk in vertebral hemangioma treated by radiotherapy. Neoplasma. 2002;49(5):338-41.

26. Mazonakis M, Tzedakis A, Lyraraki E, Damilakis J. Radiation dose and cancer risk to out-of-field and partially in-field organs from radiotherapy for symptomatic vertebral hemangiomas. Med Phys. 2016;43(4):1841.

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## Figure Legends

**Figure. 1. Illustrated Case1.** A 34-year-old female suffered from myelopathy and pain for 6 months. Frankel D. A.B. Sagittal and axial CT showed a lesion in T10. C.D. Sagittal and axial MRI. E to H. She underwent decompression and intraoperative vertebroplasty without adjuvant radiotherapy. The filling rate of bone cement is 90.2%. At the 60 months' follow-up, the patient was symptom-free with no recurrence.

**Figure. 2. Illustrated Case2.** A 69-year-old female suffered from myelopathy for 10 months. Frankel D. A.B. Sagittal and axial CT showed a lesion in T7. C.D. Sagittal and axial MRI. E to H. She underwent decompression and intraoperative vertebroplasty without postoperative adjuvant radiotherapy. The filling rate of bone cement is 90.6%. At the 12 months' follow-up, the patient was symptom-free and showed no recurrence.

**Figure. 3. Illustrated Case3.** A 25-year-old female suffered from myelopathy and pain for 4 months. Frankel C. Radiotherapy was ineffective and neurological function got worse. She underwent surgery. A.B. Sagittal and axial CT showed a lesion in T5.

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C She underwent CT-guide biopsy with negative result. D.E. Sagittal and axial MRI. F.G. Intraoperative injection of bone cement. H to J. She underwent decompression and intraoperative vertebroplasty without adjuvant radiotherapy. The filling rate of bone cement is 71.4%. At the 70 months' follow-up, the patient was symptom-free and without recurrence.

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**Table 1. Comparison of detailed information in both groups**

| Factors | Decompression Group (n=17) | Decompression+VP Group (n=22) | P |
|---|---|---|---|
| Sex (Female) | 8 (47.1%) | 17 (77.3%) | 0.091 |
| AGE | 57 (10, 67) | 43.5 (21, 69) | 0.340 |
| BMI | 24.21 (19.73, 32.15) | 23.37 (18.75, 36.73) | 0.850 |
| Preoperative embolization | 6 (35.3%) | 7 (30.4%) | 1.000 |
| Location | | | |
| Cervical | 1 (5.9%) | 1 (4.5%) | |
| Thoracic | 14 (82.4%) | 18 (81.8%) | 1.000 |
| Lumbar | 2 (11.8%) | 3 (13.6%) | |
| Smoking | 1 (5.9%) | 2 (9.1%) | 1.000 |
| HBP | 2 (11.8%) | 2 (9.1%) | 1.000 |
| DM | 1 (5.9%) | 2 (9.1%) | 1.000 |

HBP, high blood pressure; DM, diabetes mellitus; VP, vertebroplasty

**Table 2. Comparison of the surgical information in the two groups**

| Factors | Decompression Group (n=17) | Decompression+VP Group (n=22) | z | P |
|---|---|---|---|---|
| Blood Loss (mL) | 1500 (500, 4000) | 725 (300, 3000) | -2.386 | 0.017 |
| Surgery time (min) | 270 (180, 420) | 240 (150, 360) | -1.072 | 0.284 |
| Time to discharge after surgery (day) | 7 (3, 16) | 7 (4, 12) | -1.022 | 0.307 |

VP, vertebroplasty

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**Table 3. Literature review of surgical management of vertebral hemangiomas**

| Authors | No. of Pts | Treatment | Surgery Time | Blood Loss | Follow-up | Recurrence | Complications |
|---|---|---|---|---|---|---|---|
| Fox et al. (1993) | 59 | 1 total resection<br>10 subtotal resections<br>2 preoperative embolizations<br>5 adjuvant radiotherapies | — | — | 8.7 (1-17) yrs | 2/10 in subtotal resection without radiotherapy<br>1 in subtotal resection and low dose radiotherapy. | 2 profuse intraoperative bleeding<br>2 arachnoiditis<br>1 epidural hemorrhage |
| Pastushyn et al. (1998) | 86 | 64 laminectomies or extensive laminectomies with adjuvant radiotherapy for subtotal resection cases | — | — | 6-180 mos | 16 recurrences<br>7 revisions | No. |
| Doppman et al. (2000) | 11 | 11 CT-guide injections of ethanol | — | — | 15-76 mos | No | 2 pathological fractures |
| Acosta et al. (2008) | 22 | 16 surgeries: 10 preoperative embolizations<br>7 decompression surgeries<br>9 intralesional spondylectomies<br>6 vertebroplasties or embolizations | — | Mean 400 mL in patients who underwent vertebrectomy | 2-240 mos | 2 recurrences after decompression surgery | 1 excessive intraoperative bleeding |

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Kato et al. (2010) | 5 | 5 preoperative embolizations and total excisions (en bloc or piecemeal) | — | 2424 mL (1580-3400 mL) | 92-163 mos | No | No |
| Singh et al. (2011) | 10 | 10 decompressions with intraoperative ethanol embolization | 102 ± 22 min | 296 ± 90.82 mL | 12-26 mos | No | No |
| Acosta et al. (2011) | 10 | 10 preoperative embolizations and intralesional spondylectomies without adjuvant radiotherapy. | | 2100 mL (800-5000 mL) | 2.4yrs (0.8-5.5yrs) | No | No |
| Song et al. (2012) | 9 | 9 total en blocs | 210 min (180-270 min) | 1800 mL (1000-5000 mL) | 18-60mos | No | No |
| Goldstein et al. (2015 multicenter) | 68 | 33 preoperative embolizations; 17 palliative decompressions, including 3 with adjuvant radiotherapy; 37 intralesional spondylectomies, including 2 with radiotherapy; 7 en bloc spondylectomies including 1 with radiotherapy; 7 surgeries without details | — | — | Mean 3.9 yrs | Recurrence was found in 2 patients with intralesional spondylectomy, including 1 with adjuvant radiotherapy | — |
| Vasudeva et al. (2016) | 5 | 4 preoperative embolizations; 1 en bloc spondylectomy; 2 piecemeal gross-total resections; 2 subtotal resections; 3 intraoperative VPs; and 1 adjuvant radiotherapy | — | 400-1800 mL (400 and 500 mL for 2 cases of intraoperative VP) | 8-43 mos | No | CSF leak, wound infection DVT, and hardware failure in 1 case |





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No, number; Pt, patient; Yr, year; Mo, month; VP, vertebroplasty; CSF, cerebrospinal fluid; DVT, deep vein thrombosis

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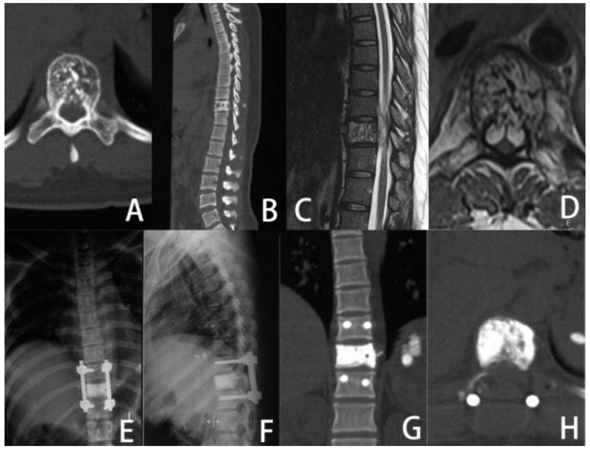


Figure1_bestsetConverted.png

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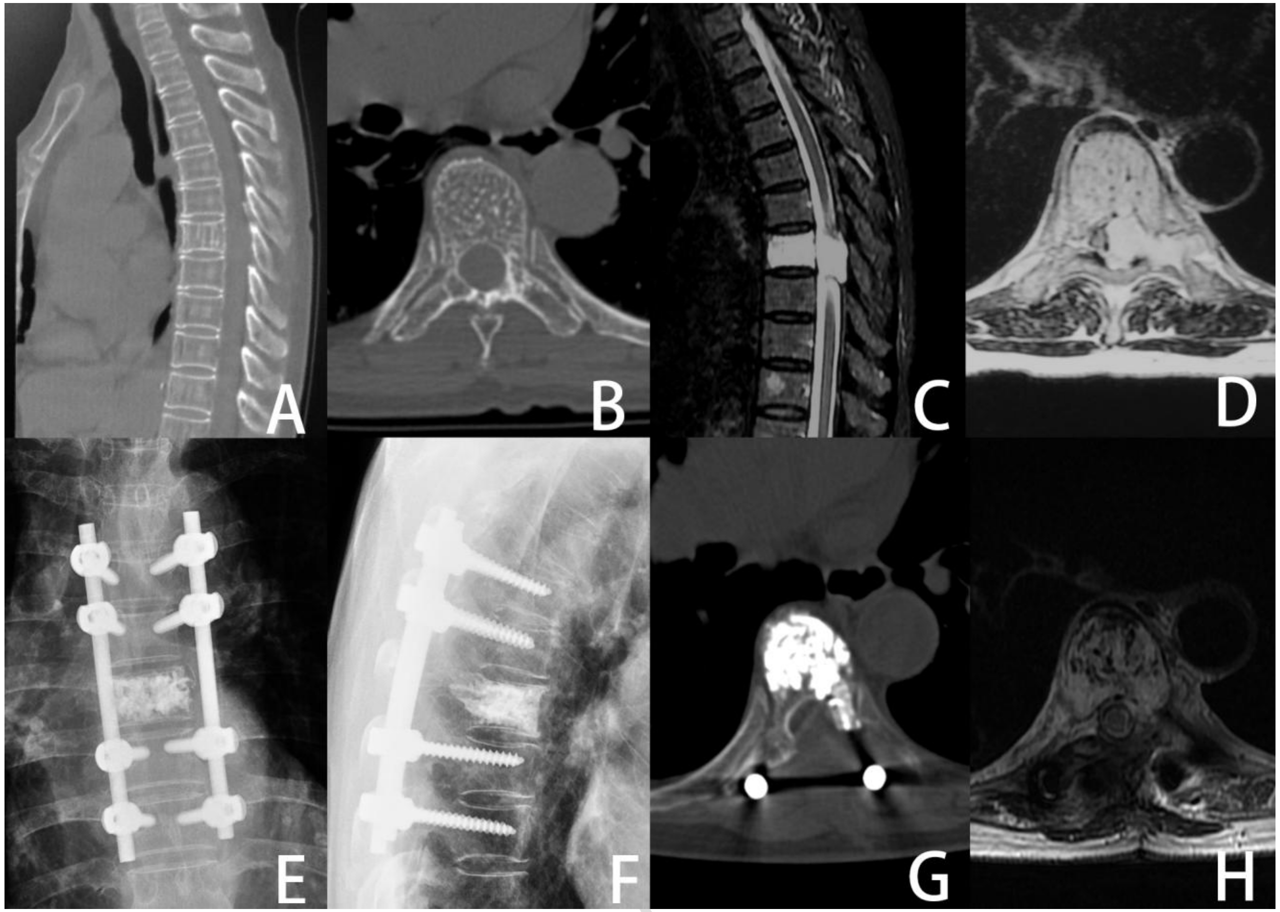


Figure2_bestsetConverted.png

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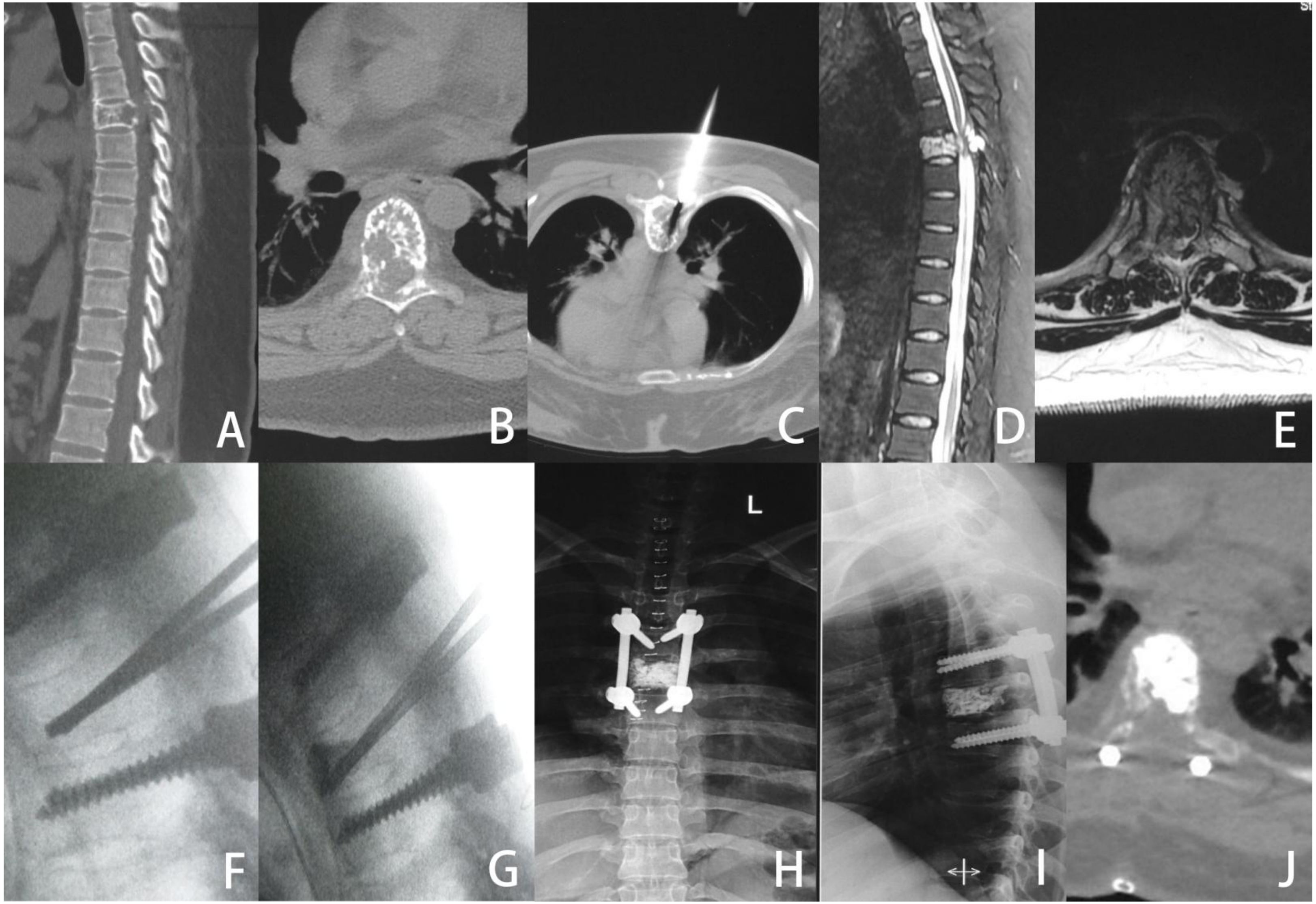

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Figure3_bestsetConverted.png

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