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IDEAS AND TECHNICAL INNOVATIONS

Preoperative elastoplasty of aggressive vertebral hemangiomas in elderly patients: a new strategy for reducing intraoperative bleeding and complications

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Abstract

Purpose Preoperative elastoplasty could be an alternative strategy for treating aggressive vertebral hemangiomas (VHs) in frail patients needing for spinal cord decompression, combining the advantages of embolization and vertebroplasty.

Methods Three elderly patients with spinal cord compression from thoracic aggressive VHs underwent XperCT-guided percutaneous injection of silicone (VK100), filling the whole affected vertebra, followed by a decompressive laminectomy. At 12-months follow-up no recurrences, vertebral collapse or segmental kyphosis were noted at the CT scans, with patients reporting an improvement of preoperative neurological deficits, VAS and Smiley-Webster pain scale (SWPS) parameters.

Results With its elastic modulus, non-exothermic hardening, and lower viscosity than PMMA, VK100 allowed a preoperative augmentation of the affected vertebral body, pedicles, and laminae without complications, with a controlled silicone delivery even in part of VH's epidural components thanks to XperCT-guidance.

Conclusion When facing highly bony erosive VH encroaching the spinal canal, VK100 combines the advantages of embolization and vertebroplasty especially in elderly patients, permeating the whole VH's angioarchitecture, significantly reducing tumor.

Keywords Vertebral hemangioma · Elastoplasty · Silicone · Augmentation · Complication · Elderly

Introduction

Vertebral hemangiomas (VHs) are benign vascular tumors with a prevalence of 41% in adult population [1]. Although they are usually asymptomatic, in 0.9–1.2% of cases these lesions may enlarge aggressively and cause pain or neurological deficit because of vertebral body or posterior arch bony expansion, VH's epidural extension compressing the spinal cord/nerve roots or because of a pathological vertebral fracture [2–4]. Surgical decompression is considered in case of neurological symptoms, although it may be treacherous, due to profuse intraoperative bleedings sustained by VH's extreme vascularity. Therefore, strategies exploiting preoperative injection of embolizing agents or various cement-like materials are advised [5, 6]. Interventional treatments for increasing vertebral stiffness and reducing blood supply to the lesion may serve as preoperative treatment for both reducing intraoperative blood loss and preventing postoperative fractures.

We report our experience with thoracic aggressive VHs in elderly patients using a percutaneous injection of a silicone elastomer bicomponent (VK100), also known as elastoplasty due to the elasticity of the injected material, followed by spinal cord decompression.

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Methods

We retrospectively analyzed data of three elderly patients admitted to our department from June 2016 to June 2020 with thoracic aggressive VHs classified as Type IV according to the Weinstein–Boriani–Biagini (WBB) classification for spinal tumors [7]. All the patients underwent thoracic spine CT scanning and gadolinium-enhanced MRI, and the images were reviewed and discussed by a multidisciplinary group. This latter approved for all the cases a double-staged combined treatment consisting of a percutaneous elastoplasty of the affected vertebra and a subsequent spinal cord decompression, respectively performed by an interventional neuroradiologist and a neurosurgeon (GL).

VK100

VK100 is a vertebral augmentation system consisting of a dispenser handle and a cartridge of 25 ml prefilled with a silicone elastomer. Born to be adopted for treating osteoporotic fractures, this material is biocompatible and each dose (VK100 material cartridge) is composed of: reinforced dimethyl methyl vinyl siloxanes, methyl hydrogen siloxane crosslinker, platinum catalyst (< 0.002%), and barium sulfate powder. This latter component makes VK100 visible at the intraoperative fluoroscopy, while silicone cross-linking occurs at room temperature, absorbing heat (endothermic), and restarting every time material is added, thus without activating chemicals. At the usual temperature of an operating room the VK100 hardens in 12 min with a final elastic modulus of 233 ± 14 N/mm much more similar to the trabecular bone one (120–180 N/mm) than the elastic modulus of PMMA (1730–1770 N/mm). These characteristics allow a typical intravertebral distribution of the silicone elastomer, through a pressure gradient, with an enhanced trabecular bone interdigitation.

Percutaneous elastoplasty

All the procedures were performed with patients under general anesthesia, in prone position, and integrating cone beam CT and biplanar angiography. Under high resolution fluoroscopy and cone beam CT guidance bilateral transpedicular needles of 11 gages were introduced in the affected vertebral bodies through a percutaneous approach. After having collected biopsy samples both from the pedicles and the vertebral body, the tips of the needles were inserted at the ventral edge of the lesion to fill the VH with as much silicone as possible (VK100, BonWrx Inc.—Lansing MI, US). The injected material starts hardening after its two substances, in separated cartridges, are pushed through a mixing element composing the final product. As the silicone augmentation reached the posterior wall of the vertebral body, partially permeating the ventral epidural component, both the needles were gradually retracted, while continuing the silicone injection until fulfilling the pedicles and obtaining a partial spreading of VK100 in the laminae and in the lateral intracanal component of the tumor itself [8].

Surgical technique

After the percutaneous elastoplasty the patients were transferred in the contiguous operating room, preserving sedation, then positioned prone. The vertebral level above and below the VH were exposed through a midline longitudinal incision. After having uncovered the facet joints, the vertebral level was checked by fluoroscopy and the adjacent caudal and cranial laminae were partially removed to identify few millimeters of the normal dural sac, thus minimizing the posterior decompression. Laminectomy of the affected vertebra was performed, and the medial wall of the pedicles was removed using a diamond burr. A satisfactory decompression was obtained by shrinking the epidural component of the tumor through bipolar coagulation and removing it in a piecemeal fashion until achieving a complete release of dural sac and nerve roots. Intraoperative blood loss was calculated on the weight of the soaked surgical sponges and with the volume in suction canisters, subtracting the irrigation fluid sprinkled on the surgical field. A drainage was positioned in all the patients, left in place for two days, and its volume of drainage was included in the data collection on blood loss.

Results

Case 1

An 84-year-old woman presented with complaints of difficulty in walking due to lower limbs weakness for two months and increasing dorsal pain (VAS 7/10). Neurological examination revealed a spastic paraparesis, a power of 3/5 in the right lower limb and 4/5 in the left one, and an associated sensory loss below the D9 dermatome. A CT scan and an MRI of the spine showed the classical findings of a D5 aggressive VH (Type IV—WBB classification) with an eccentric epidural compression on the right side. The patient underwent D5 laminectomy and decompression of the epidural component, preceded by percutaneous D5 elastoplasty, fulfilling vertebral body and pedicles (Fig. 1). Intraoperative blood loss was 830 ml, while the volume of postoperative drainage was 230 ml. No blood transfusions were needed. The postoperative course was uneventful, with physiotherapy started on the third day after surgery, and the patient transferred to a neurorehabilitation center after four days.

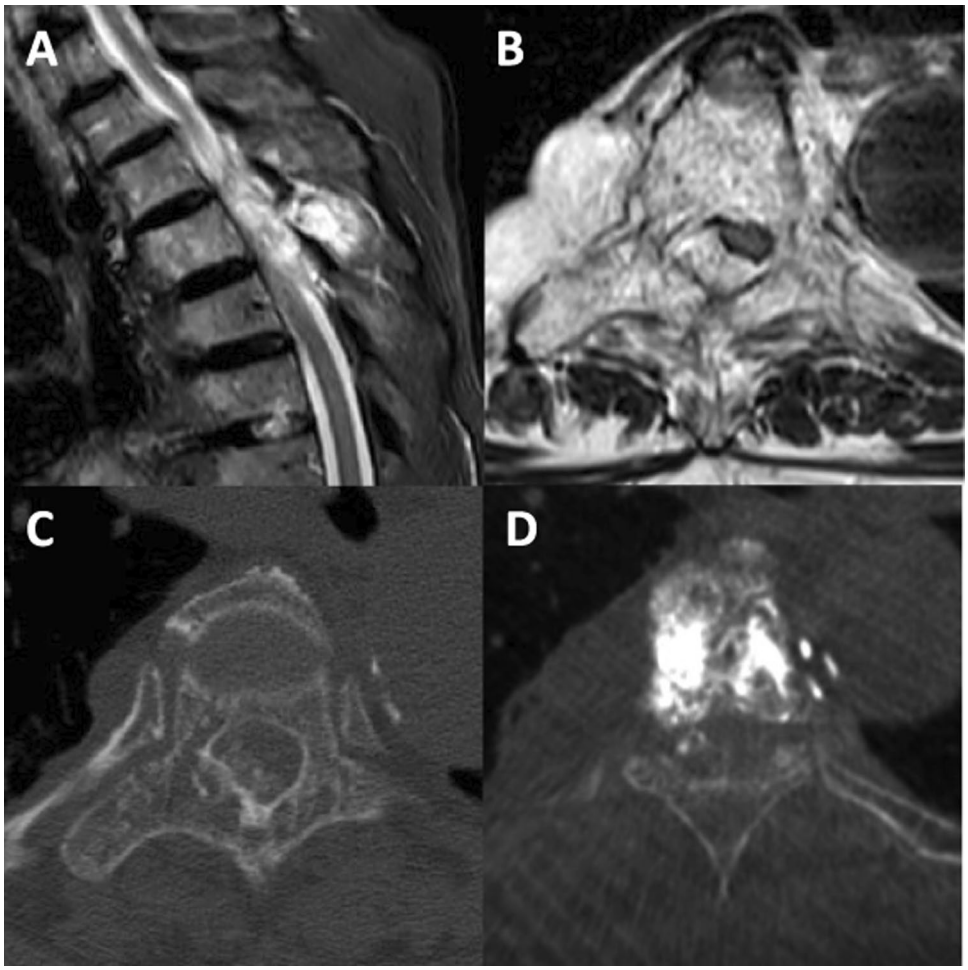

Fig. 1 Preoperative MRI (**A**, **B**) and CT scan (**C**) showing the D5 aggressive VH with an eccentric epidural compression on the right side; vertebral body augmentation of the VH with VK100 (**D**)

Case 2

A 71-year-old man was admitted to our division for a progressively worsening spastic paraparesis, sphincter disturbances with urinary retention, and dorsal throbbing pain (VAS 7/10). On the neurological examination the patient had a lower limb power of 4/5 and a sensory loss below the D5 dermatome. A CT scan and an MRI of the spine revealed a D3 aggressive VH (Type IV—WBB classification) with a posterior spinal cord compression. The patient underwent percutaneous elastoplasty of D3, including the vertebral body, the pedicles, part of the facet joints, and of the soft component of the hemangioma stuffing both laminae and spinous process (Fig. 2). A subsequent decompressive laminectomy was performed along with removal of the epidural component of the VH. Intraoperative blood loss amounted to 860 ml, while the postoperative drainage collected 210 ml. No blood transfusions were needed, and an improvement of the hyposthenia was observed immediately after surgery. On the ninth postoperative day the patient was discharged with an outpatient rehabilitation program.

Case 3

A 74-year-old woman suffering from chronic renal failure developed a progressive hyposthenia in the lower limbs and intense back pain (VAS 8/10). Neurological examination showed a spastic paraparesis with a lower limb residual strength of 3/5 and distal dysesthesia with hypopallesthesia below the D12 dermatome. The MRI and CT scan of the spine revealed a D11 VH (Type II—WBB classification) and a myelopathy sustained by a D12 aggressive VH (Type IV—WBB classification), determining a circumferential spinal cord compression. After undergoing percutaneous elastoplasty of D11 and D12, with VK100 fulfilling vertebral body, both the pedicles, and accidentally permeating even part of the epidural component (Fig. 3), the patient underwent D12 laminectomy and decompression of the intracanal tumor choking the spinal cord. Surgery was influenced by a blood loss of 1020 ml, requiring the transfusion of three units of concentrated red blood cells, which adequately compensated the intraoperative bleeding. After one day in intensive care unit, the patient returned to our division without reporting complications, and on the second postoperative

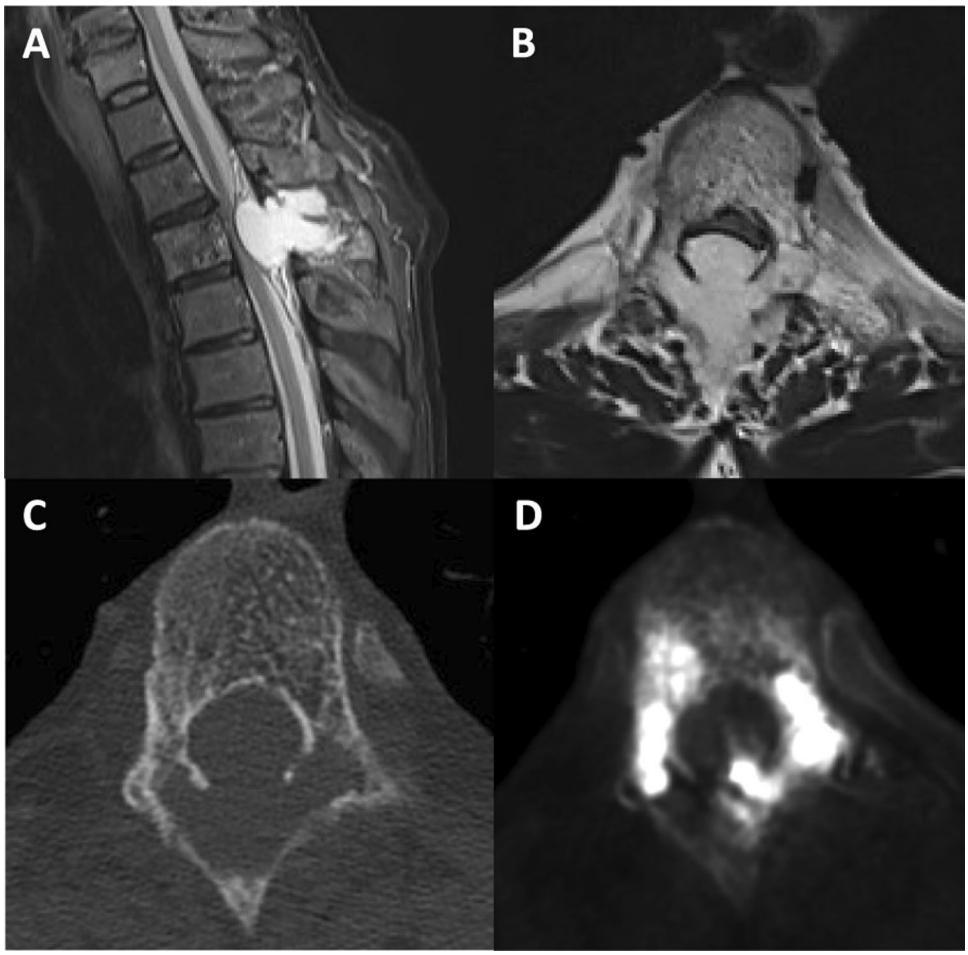

Fig. 2 Preoperative MRI (**A**, **B**) and CT scan (**C**) showing the D3 aggressive VH with its epidural component sprouting from the laminae and spinous process; XperCT scan (**D**) documenting the fulfilling of the pedicles with VK100 and its spreading along the lamina and the epidural component of the tumor

day a total drainage of 190 ml was recorded. The subsequent course was surprisingly positive with patient being able to walk with support on the third postoperative day and complete blood count normalizing to preoperative values five days after surgery. On the eighth day the patient was discharged to home.

Clinical and radiological outcome

At 12-months follow-up all the patients reported a significant improvement of their preoperative neurological deficit with case 1 and 2 being able to walk autonomously, but with residual episodic paresthesia below their dermatome levels respectively involved by the aggressive VH. All the three patients were referred to a rehabilitation program for six months, but only case 3 is still followed up as outpatient by her physiatrist, being walker dependent for her daily activities. At 12 months after surgery, the VAS scores registered in case 1, 2, and 3 were respectively 1/10, 2/10, and 2/10, while the Smiley-Webster Pain Scale (SWPS) was good in case 1 and 2, while fair in case 3. None of the three patients were treated with radiation therapy. No radiological recurrences, vertebral collapse or postoperative segmental kyphosis were documented at 12-months CT scan (Fig. 4).

Discussion

When facing aggressive VHs causing spinal cord compression, pathologic vertebral fracture, or spinal instability, active treatment is usually required [9]. Many options have been proposed, currently including endovascular embolization, alcohol ablation, and vertebroplasty with bone cement, surgery, radiotherapy, or any combination of these techniques [3, 4, 10–12]. Although en bloc vertebrectomy or piecemeal gross total resection can effectively reduce tumor recurrence, the high risk of complications and massive intraoperative blood loss related to these procedures, together with the relatively benign biological properties of aggressive VHs, have led to prefer decompression surgery with-or-without posterior instrumentation [2–5, 9, 12–15]. Less invasive surgical strategies result even more reasonable in elderly patients, considering the relatively low risk of VH recurrence, which is usually in the long-term period [2, 16, and 17]. Laminectomy combined with embolization with

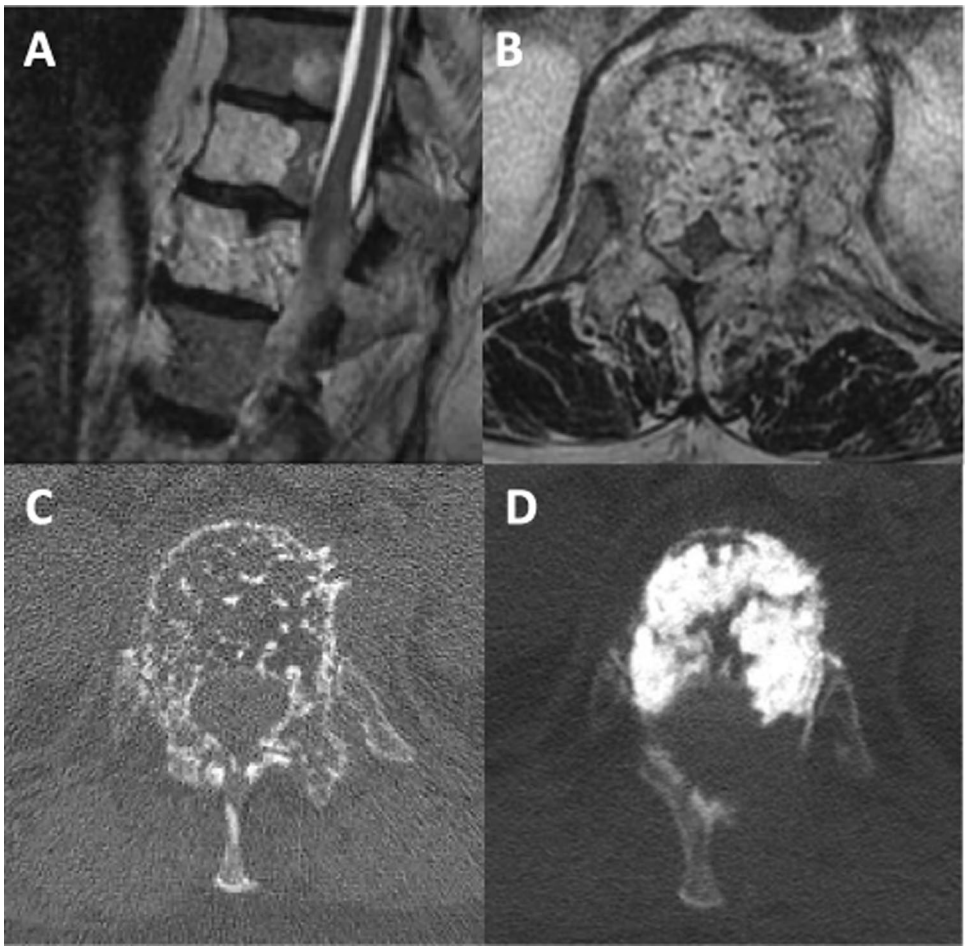

Fig. 3 Preoperative MRI (**A**, **B**) showing the D11 and D12 VHs with D12 circumferential epidural component choking the spinal cord; preoperative CT scan documenting the typical irregular honeycomb pattern of VHs; postoperative CT scan (**D**) demonstrating the fulfilling of D12 vertebral body with VK100 and its limited spreading in the left epidural component of the tumor

ethanol [3, 6], polyvinyl alcohol (PVA) particles [9, 18, 19], onyx [20], N-butyl cyanoacrylate (NBCA) [4], or associated with vertebroplasty [13, 14, 21] have been proposed. Although the endovascular treatments reduce intraoperative bleeding occluding feeding vessels [19, 20, 22], nevertheless the transarterial injection of ethanol exposes to the risk of local or systemic side effects due to its rapid "run off" in the neighboring districts and its toxicity on vascular endothelium [3, 5]. Given these complications, new materials such as PVA and onyx have been introduced. However, although safer, the use of these embolizing agents is not risk-free, with accidental closure of other vessels and recanalization of the embolized ones reported in different studies [18, 20]. In this sense, transpedicular embolization represents an alternative when the transarterial procedure is unsafe or the feeding vessels supply the artery of Adamkiewicz as well as the VH. With the transpedicular technique a risk of pathological fracture, osteonecrosis, spinal cord injury, and asystole was reported with ethanol direct intralesional injection [6, 18, 23, and 24]. Adopting other embolizing agents, even when no complications occur, the transpedicular treatment can reduce the risk of bleeding by occluding the arterial vessels, but it has no effects on the vertebral body structure, thus not reducing the risk of vertebral collapse [25].

Vertebral augmentation with bone cement, instead, determines the consolidation of trabecular microfractures, which underlay the chronic pain worsening with the axial load, and the intralesional embolization of small vessels and cavernous channels [9], along with a reported shrinkage of the epidural component due to decreased blood supply [12, 13, 26]. Polymethylmetacrylate (PMMA) exothermic polymerization produces heat which determines intralesional thrombosis and relieves pain by ablation of pain sensitive vertebral nerve endings [17, 18]. However, although this exothermic polymerization may produce a thermal damage to spinal cord or nerve roots in case of a PMMA leakage [2], the most commonly reported complication is the mass effect on spinal cord determined by cement leakage [9], with PMMA intracanal hunks extremely difficult to remove. Moreover, this procedure makes the treated vertebra stiffer and heavier, thus increasing the risk of an adjacent segment fracture [9]. This aspect may be particularly relevant when facing VHs, which can be multiple up to 30% of the cases [6], configuring a multilevel vertebral fragility scenario.

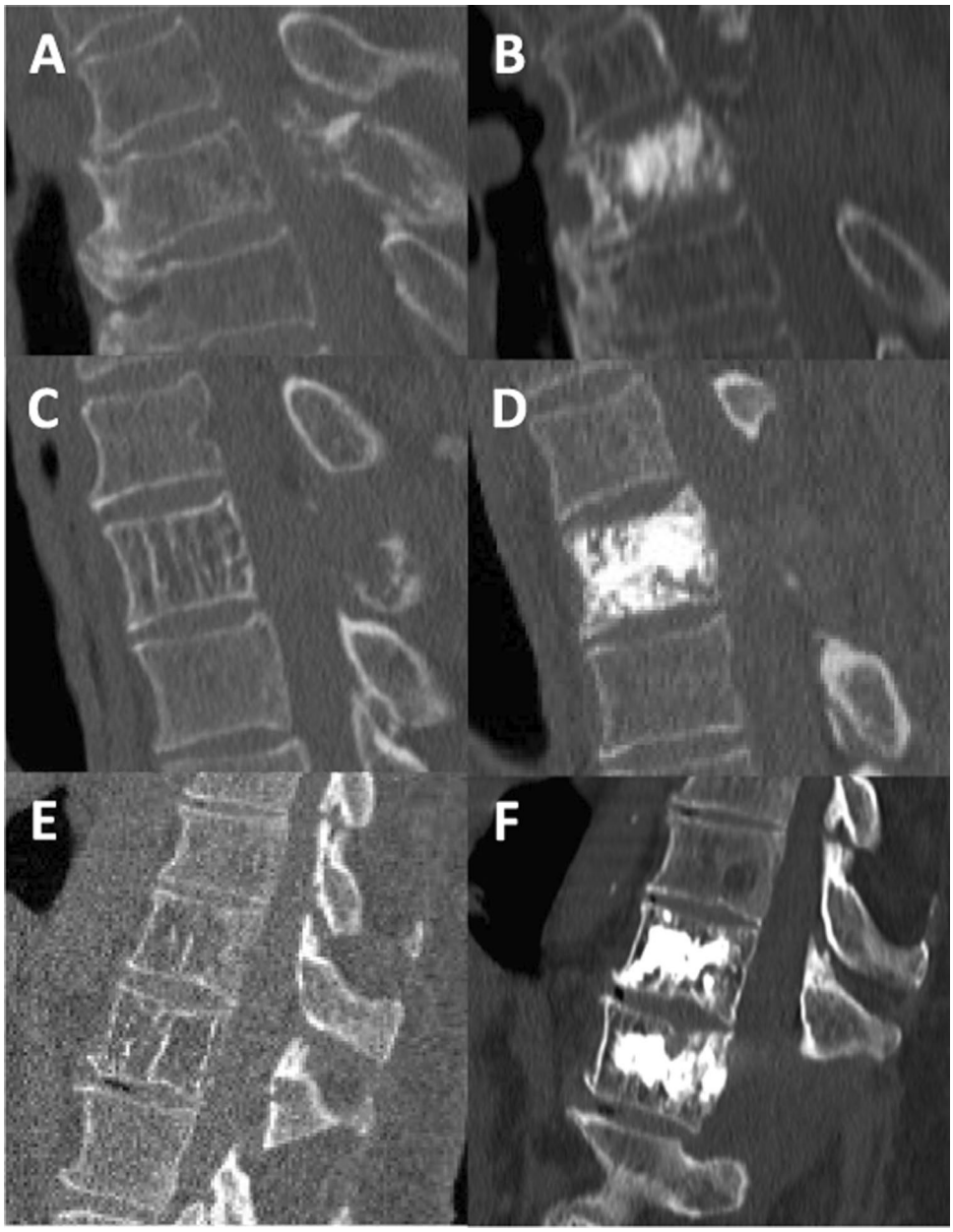

Fig. 4 Preoperative and follow-up CT scans of the three cases (**A**-**B**: case 1; **C**-**D**: case 2; **E**-**F**: case 3), documenting the absence of postoperative segmental kyphosis, recurrences, or adjacent vertebral collapses at 12 months

Starting from this report and considering a further age-related risk for osteoporotic fractures in elderly patients, we have been approaching a new strategy for their management, based on the preoperative percutaneous injection of VK100 before decompression surgery, in a two-steps single stage procedure. Engineered to have a stiffness similar to the cancellous bone, the VK100 is an elastic material with limited space occupying effect and lower viscosity than PMMA, which flows between the trabeculae, not breaking them but filling the space among them when it is hardened (Fig. 5). Since, VK100 has a working time of 12 min and it is nonexothermic, it allowed a cone beam CT-guided gradual fulfilling of vertebral body, pedicles, and laminae with a controlled distribution of the silicone, with no reported complications to date.

Intraoperatively, we observed less bleedings than expected with an average blood loss of 903 ml. Although measured in a limited patient sample, this volume is in line with the 968.33 ± 287.78 ml and 957.78 ± 109.86 ml reported by Xu et al. [9] in their patients, respectively treated with polyvinyl alcohol (PVA) embolization ($n = 16$) and vertebroplasty ($n = 19$) before laminectomy. Similarly, Wang et al. [12] reported an average blood loss of 1068.2 ml in their 22 patients undergone decompression plus intraoperative vertebroplasty, while Huang et al. and Prabhuraj et al. documented intraoperative bleedings of 1226.5 ± 151.2 ml

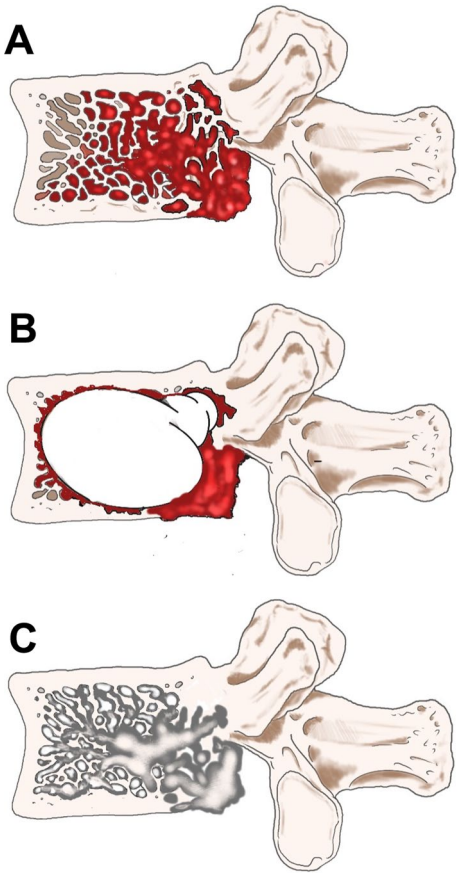

Fig. 5 Illustration of hypervascularity of aggressive VH destructively violating the posterior wall of the vertebral body (**A**); mass effect of PMMA distribution pattern (**B**); capillary intralesional distribution of VK100 (**C**)

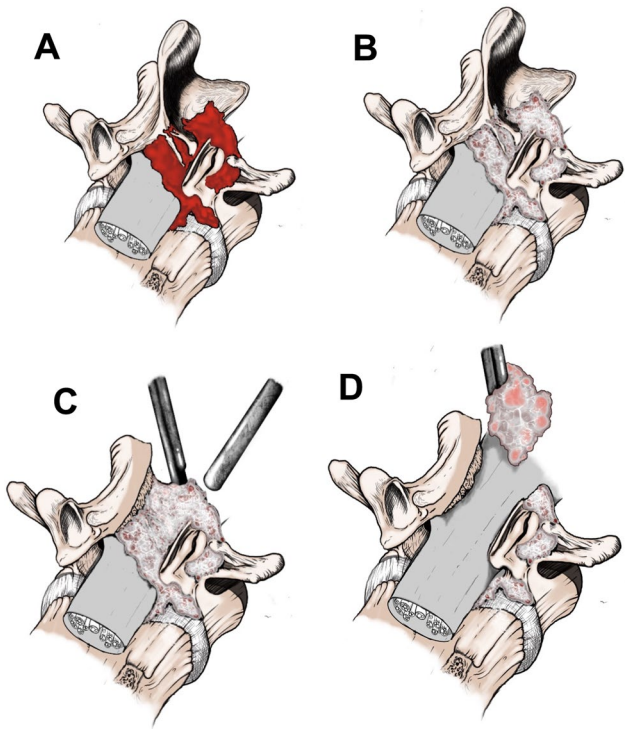

Fig. 6 VK100 completely permeates aggressive VHs also along pedicles and laminae (**A**, **B**) thanks to its low viscosity, while its elastic modulus facilitates the dissection from the dural sac and its removal (**C**, **D**)

and 920 ml, respectively with preoperative vertebroplasty ($n = 17$) and NBCA embolization ($n = 5$) [4, 13]. Nevertheless, our mean blood loss volume was higher than the 511 ml reported by Singh et al. and Chandra et al., who injected ethanol before the posterior decompression [3, 6], and much more than the one registered by Corniola et al. [5] (< 50–500 ml) adopting a combination of embolization with histoacrylic glue (Glubran2), vertebroplasty, and percutaneous injection of sodium tetradecyl sulfate (STS) in their five patients.

Although with the limitation of only three cases treated, in our experience preoperative elastoplasty may combine the advantages of embolization and vertebroplasty procedures, since VK100 permeated the whole VH's angioarchitecture extensively, significantly reducing tumor hypervascularity. Even without the heat-related shrinkage of the hemangioma provided by bone cement during its polymerization, VK100 reduced intraoperative bleedings, while ensuring an adequate anterior column support with a low risk of adjacent segment fracture thanks to its elastic modulus. Moreover, the absence of an exothermic polymerization and the gummy consistency of VK100, reached after its hardening, allowed a safe fulfilling of vertebral body and pedicles with a reduced risk of injuring the neural structures in case of a leakage, since, when this latter occurred, the epidural silicone aggregates resulted easy to be removed (Fig. 6). In fact, likely the absence of exothermic polymerization creating adhesions and the elastic modulus of VK100 made silicone smoothly respectable from the dural sac through an easy cleavable plane, thus allowing safe spinal cord decompressions combining coagulation and piecemeal resection of epidural tumor infiltrated by VK100, when this latter leaked (Fig. 7).

Considering the geriatric age of our patients and the absence of intraoperative findings of instability after decompression, we did not perform posterior arthrodesis for avoiding further intraoperative risks and potential postoperative complications related to a stiffer and heavier spinal segment over the vertebrae below. In this sense, the percutaneous injection of VK100 was strategical for providing a satisfactory augmentation without increasing the risk of adjacent vertebral fractures, especially in aggressive VHs where, differently from osteoporotic fractures, the vertebral body has to be entirely full filled with augmentation materials [13, 27]. At 12 months follow-up our three patients reported a significant improvement of their neurological function and

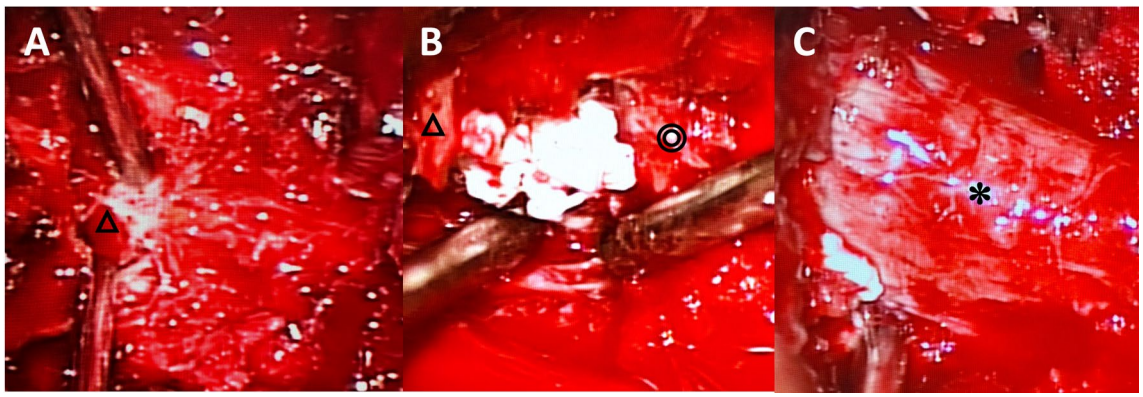

Fig. 7 Intraoperative views of the progressive posterior decompression in case 2, showing the whitish appearance of VK100 inside the lamina (**A**) and the piecemeal removal of its white aggregates infiltrating the epidural tumor from the posterior surface (**B**) and the lateral aspect (**C**) of the dural sac. △ lamina, ◎ epidural component of VH, ✻ dural sac

back pain scores, without any symptom of spinal instability, radiological recurrences or complications.

Conclusion

Over the years, preoperative embolization and vertebroplasty have been progressively adopted for the management of aggressive VH, due to their safety profile, the reduced risk of profuse intraoperative bleeding, and the higher feasibility in elderly or frail patients. From our preliminary experience, although in an extremely limited case series, the VK100 could represent a valid alternative, not only for those patients in whom there may be contraindications to endovascular treatment, but even more in those patients with an extensive bony erosion and spinal cord compression, and in severely osteoporotic patients with higher risk of adjacent vertebral fractures. The integration of elastoplasty in our armamentarium may help in containing intraoperative bleeding, thanks to the capillary and controllable distribution of the silicon, even close to the neural structures, with a minimal risk of complications.

In this process, cone beam CT-guided augmentation performed by the interventional neuroradiologists was crucial to full fill the whole vertebra, thus maximizing the permeating capacity of VK100 in a high tumor volume, optimizing its devascularization.

Due to the rarity of aggressive VHs, particularly in geriatric patients, further studies with larger patient samples and longer follow-up are needed to confirm both safety and effectiveness of preoperative elastoplasty before posterior decompression. According to our experience, we would encourage the use of silicone even in younger patients with aggressive VHs, since we believe that its properties, adequately maximized by a preoperative cone beam CT-guided augmentation, could also help when en-bloc or subtotal resections are more appropriate.

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Declaration

Conflict of interest The authors have no conflicts of interest to be disclosed.

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