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IDEAS AND TECHNICAL INNOVATIONS

Bone marrow washout for multilevel vertebroplasty in multiple myeloma spinal involvement. Technical note.

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Abstract

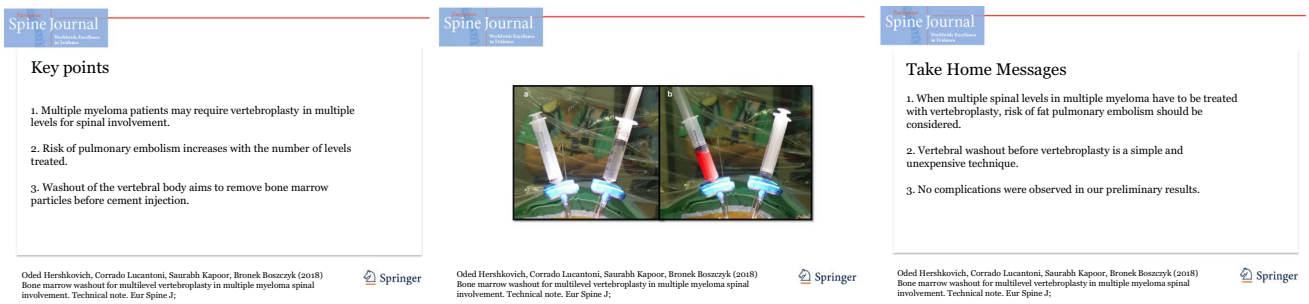
Introduction Vertebral involvement is found in a high percentage of multiple myeloma (MM) patients, often requiring multilevel surgical treatment to reduce pain and disability and to receive prompt access to oncological care. We describe the clinical use of washout technique for multilevel vertebroplasty in MM patients with diffuse spinal involvement. The aim of this technique is to reduce the risk of pulmonary fat embolism after cement injection and possibly to increment the amount of cement and treated levels in one surgical stage.

Methods Three patients were treated with the washout technique prior to multilevel vertebroplasty for thoracolumbar diffuse spinal involvement in multiple myeloma. We describe the surgical technique and review the pertinent literature.

Results The technique is clinically safe and effective in reducing pain, without significant complications. Two six-level vertebroplasties were performed in one case, allowing a larger amount of cement injected and a prompt start of the oncological treatment.

Conclusions Multilevel vertebroplasty in MM patients with diffuse spinal involvement carries the advantages of reducing pain, avoid repeated surgeries and faster return to oncological regimen. Cardiovascular complications, including pulmonary embolism, are rare but can have fatal consequences. It is mainly due to bone marrow mobilization during cement injection and the risk increases with the amount of cement injected and the number of treated levels. Despite multilevel treatment at the same stage, we did not observe any significant complication in our series. Further studies are needed to confirm the preliminary results of this technique.

Graphical abstract These slides can be retrieved under electronic supplementary material.



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Keywords Multiple myeloma · Vertebroplasty · Fat pulmonary embolism · Vertebral washout · Lavage

Introduction

Multiple myeloma (MM) is a neoplasm resulting from proliferation of plasma cells invading the bone marrow, involving the spine in a high percentage of patients [1] and resulting in fragility fractures, back pain, early muscle fatigue, ambulation difficulties and a substantially decreased quality of life. Vertebroplasty is a vertebral augmentation technique that has been shown to be efficacious and safe for vertebral involvement in MM [2] and can be a valid adjunct to the conventional treatment with chemotherapy and radiotherapy. In some cases, multilevel augmentation is required in order to reduce the pain and stabilize the diffusely affected spine [3]. Multilevel procedures avoid repeated operations and allow a quicker access to oncological pathway. The main concern of multilevel vertebroplasty is the cardiovascular risk related to pulmonary embolism [4], which raises with the number of levels to be treated [5] and it is difficult to control with the current vertebroplasty techniques. A vertebral pulsed jet lavage technique to remove "wash out" the bone marrow from the vertebral body prior to cement injection has been previously described in cadaver and animal models [6, 7], and in one clinical study for osteoporotic vertebral compression fractures [8], aiming at reducing the injection forces, improving the distribution of the cement, and most importantly, possibly reducing the risk of cardiovascular events [8, 9]. Scope of this paper is to describe our early clinical experience on the use of vertebral bone marrow washout technique in multiple myeloma, elucidate its clinical safety and discuss the possible effects on decreasing the risk of fat embolism. Important clinical benefits of it are a safer multilevel surgical procedure for patients suffering from MM with multiple spinal levels involvement awaiting treatment and a shortening of the waiting time to start the pending chemotherapy treatment.

The surgical technique

Patients were under general anaesthesia. The number of stages required was based on the patients' medical condition to withstand a long procedure, the number of vertebrae to be augmented based on preoperative imaging and the oncological plan. Patients were placed in prone position. Bilateral Jamshidi needles of 3 mm diameter were inserted under fluoroscopic guidance. A classic transpedicular route was used for lower thoracic and lumbar vertebrae, while a transcostovertebral route [10] was used for higher thoracic levels, according to the size of the pedicles. Two 50-ml syringes were used to flush each vertebral body. While injecting saline with one syrinx from one side, the contralateral one was used by the assisting surgeon to gently aspirate, allowing for a continuous washing flow (Fig. 1). After repeating the procedure for a total lavage of 100 ml, the polymethylmethacrylate bone cement (Vertecem V+, DePuy-Synthes, West Chester, Pennsylvania, United States) was inserted with a bi-pedicular technique under fluoroscopic guidance until a satisfying filling of the body was achieved (Fig. 2). The amount of cement injected varied depending on the vertebral level, being higher on the lumbar levels due to the bigger size of the vertebrae. The procedure was repeated for each planned level, for a maximum of six levels for procedure.

Procedure-related experience

The washout technique was used for multilevel vertebroplasty in spinal MM patients without spinal cord compression at our centre in three patients, according to multidisciplinary discussion with our haematology team. Demographic and procedure data are summarized in Table 1. Mean age of the patients was 63.3 years.

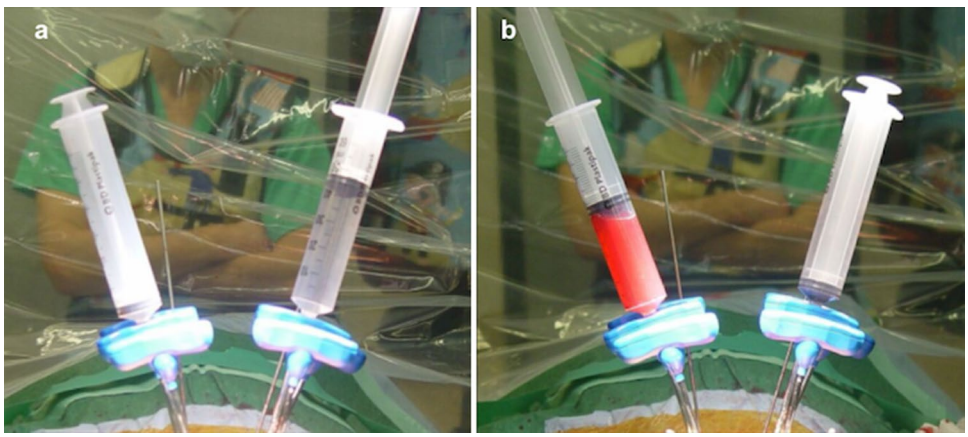

Fig. 1 After the insertion of the Jamshidi's needles, the washout technique consists of a pulsed lavage of the vertebral body with 100ml of saline (50-ml syrinx lavage, repeated twice), while drawing with the contralateral syrinx at the same time (**a**). A mix of saline and blood can be observed in the drawing syrinx (**b**)

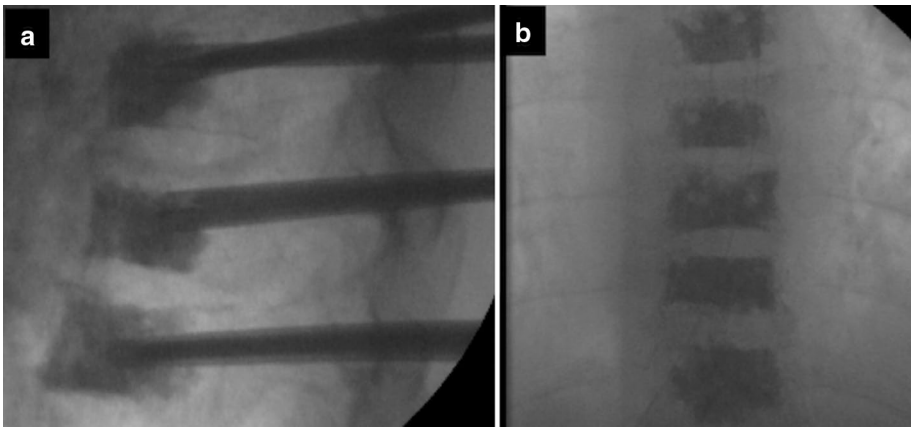

Fig. 2 The PMMA cement is injected in all the planned vertebrae through the Jamshidi's needles (**a**), under fluoroscopic guidance to control possible leakage. Injection is stopped when there is a good distribution of the cement or a significant cement extravertebral or intracanalar leakage is evident. Final fluoroscopic control is obtained in lateral and anteroposterior view (**b**)

Table 1 Demographic and surgical procedures data

Patient	Sex	Age (ys)	Levels treated (previous stages)	Levels treated (last stage)	No. of treated levels (total)	Cement injected after washout (ml)	Adverse events
Case 1	M	69	T7, T10, L3 T11, T12, L1, L2 T4, T5, T6, L4, L5	T8, T9 (washout)	14	7.5 (2nd)	–
Case 2	M	65	T10, T11, L1, L2 (washout)	–	4	21	T10 Leak, stopped procedure-Small temporary (10 s) ventricular ectopic
Case 3	M	56	T11, T12, L1, L2, L3, L4 (washout)	T5, T6, T7, T8, T9, T10 (washout)	12	36 (1st) 12 (2nd)	–

Case 1

A 69-year-old male with a known multiple myeloma and recurrent back pain underwent a two-level vertebroplasty (T8 and T9) with washout technique. Patient had already been treated before with multilevel vertebroplasty for diffuse spinal MM involvement in multiple stages, with previous three-level, four-level and five-level stages. No peri- or post-operative complications were observed. Patient was mobilized the day of the surgery, with good pain control. Control X-ray showed no complications.

Case 2

A 65-year-old male with multiple myeloma and thoracolumbar junction back pain underwent a four-level VP (T10-L2) with washout technique. A small leakage during the last cement injection (T10) was detected at fluoroscopy. After that, a short ectopic ventricular rhythm lasted for 10 s. The rest of the procedure and post-operative course were uneventful. A total of 21 ml of cement was injected in the four levels. Patient was mobilized on the same day of the surgery with a good pain control. Control X-ray was obtained, showing no radiological complications.

Case 3

A 56-year-old male with a few months history of back pain and evidence of diffuse spinal MM involvement (Fig. 3a, b) underwent a two-staged procedure for augmentation of totally 12 thoracolumbar spine levels. In the first procedure, six levels (T11-L4) were treated with vertebral washout and VP, and the other six levels (T5-T10) were treated with the same technique in a second procedure after 2 weeks. In the first procedure, a total amount of 36 ml of cement was injected, 12 ml in the second. No peri-operative or post-operative complications were observed. A significant reduction in the pain was observed, patient was able to mobilize on the same day. A 3-month follow-up whole spine X-ray was obtained, showing no radiological complications and good distribution of the cement in the treated levels (Fig. 3c).

Discussion

Multiple myeloma is characterized by the proliferation of plasma cells derived from B-cells within the bone marrow, proliferating and promoting bone resorption, suppressing osteoblast activity and causing imbalance between increased

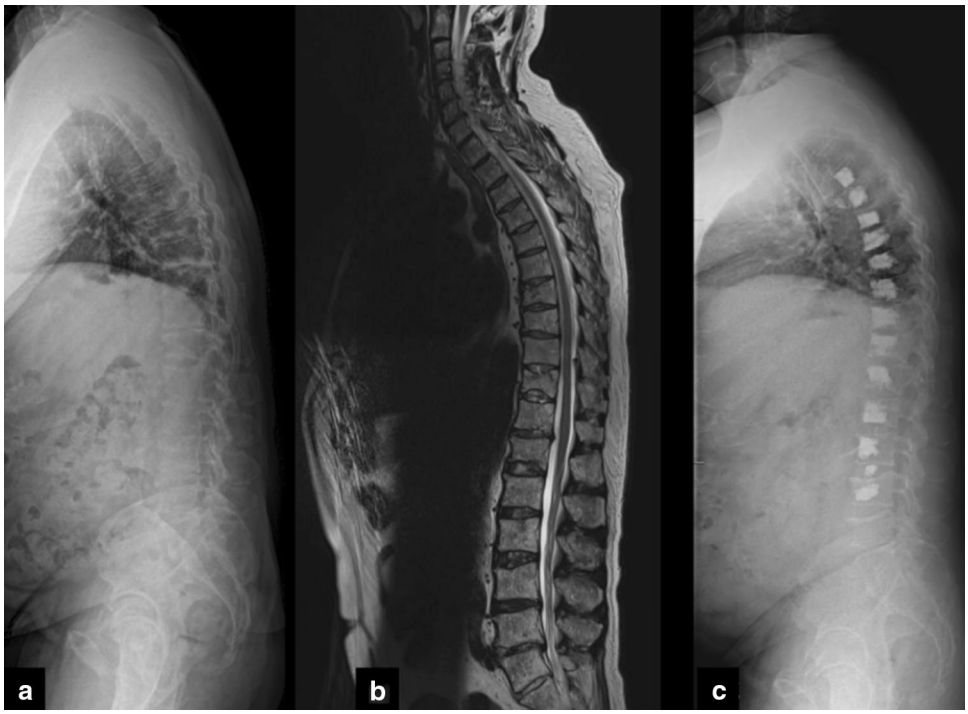

Fig. 3 **a** Standing X-ray of patient 3. **b** Whole spine MRI showing diffuse spinal bone marrow involvement by multiple myeloma in the same patient. **c** Post-operative X-ray showing good distribution of cement, with only small anterior leakage at L3 and T5 and a leak in the L2-L3 disc, without clinical significance

osteoclastic bone resorption and decreased bone formation [11]. The result is skeletal destruction that manifests as bone pain and fractures. Up to 90% of MM patients develop bone lesions and it is estimated that over 60% of bone lesions occurring in MM patients involve the spine [1]. Vertebral involvement may appear as generalized osteoporosis, osteolysis areas or vertebral fractures of which over 80% occur in D6-L4 region and appear as endplate alterations, wedge deformities or vertebral collapses, causing chronic pain, reduction in mobility, spinal deformities, pulmonary and neurological complications [12]. Non-surgical treatments include chemotherapy and radiotherapy. Vertebral augmentation with polymethilmetacrylate (PMMA) is a common surgical procedure in MM patients, in order to stabilize the affected spine, reduce the pain and prevent vertebral collapse. It has been shown that vertebral augmentation is effective in reducing the pain and decreasing the analgesic use [2], given biomechanical effects [13], effects on pain receptors and direct cytotoxic effect [14].

Multilevel VA procedures in MM patients, treating multiple vertebrae in the same surgical stage, may be a necessary and an appropriate treatment for fractures and pain [3] in combination with chemotherapy and radiotherapy, avoiding repeated surgical procedures and increasing the chances of pain relief [2] when it is not easy to specifically localize the pain to a specific level. Moreover, few reports have focused on the option of treating all the affected levels with a small number or a unique procedure to allow patients returning sooner to their MM oncology regimen, improving disability and possibly preventing sagittal deformity [15].

Among complications of vertebroplasty, cardiovascular issues are rare (< 0.1%) [2] and include myocardial infarction and pulmonary embolism, that can manifest as a fat embolism syndrome up to 36 h after surgery, with petechial rash, tachypnea, dyspnea, tachycardia, pyrexia, oliguria and thrombocytopenia [4, 16]. They are probably due to the rise in the intraosseous pressure during augmentation, which leads to mobilization of bone marrow into the circulation, or to decrease in the sympathetic tone, rather than to the PMMA toxicity [4]. Augmentation of multiple vertebral bodies increases the incidence of embolic events [17]. Although rare, embolic phenomena can have fatal consequences [15, 18] and are difficult to prevent, especially when multilevel procedure is planned. Thus, a limit of three or four treated vertebrae [5] or a maximum of 30 ml of cement injection per session [19] have been previously suggested.

However, even if the highest percentage of patients described in the literature undergo vertebral augmentation for up to three levels, several studies have reported on the treatment of more than three levels in the same procedure for tumour, osteoporosis and multiple myeloma [20–22].

Beside the use of high viscosity cement [23], several techniques to reduce cardiovascular complications have been proposed, including sequential eggshell technique cement injection [24], specially designed aspiration cannulas [25], enhanced pathology control [26] and patient positioning to increase intrathoracic and intra-abdominal pressure [19].

The technique and the possible clinical advantages of "washout" or lavage has been described firstly by Benneker et al. [6], observing in a cadaveric spine model and then in

an animal model [7] the utility of lavage in reducing cement injection forces, distributing more homogenously the cement and reducing extravasation. The same group described the ability of jet lavage in reducing the fat embolic load to a degree below the threshold for eliciting a cardiovascular response in an animal model [9] and reported the advantages and safety of the technique in clinical setting in a series of osteoporotic vertebral compression fractures [8], including the reduced risk of cement leakage and the potential to prevent pulmonary embolism. To our knowledge, the advantage of this technique in increasing the amount of cement injected has not been reported.

Multiple myeloma includes a group of patients that frequently need multidisciplinary treatment and staged procedures in order to treat their diffusely involved spine. In our early clinical experience, the first two levels case allowed us to verify the safety of the technique in patients with multiple myeloma, which was later on used on the second patient for a four levels vertebroplasty. A visible leakage on fluoroscopy was an indication to stop the injection at that level, but that was the last planned and the procedure was completed successfully. In the third case, the washout technique allowed to perform 12 levels vertebroplasty in two procedures (six in the first stage and six in the second stage), allowing the patient early return to the oncological pathway. A total amount of 48 ml was injected without complications, suggesting that the washout could possibly increase the amount of cement injected above the usual limit of about 25–30 ml.

Even if the already low risk of pulmonary fat embolism in multi-segmental vertebroplasty is difficult to compare with our small series, in our experience the washout is a simple technique that can reduce the number of staged vertebroplasty procedures in patients with diffuse multiple myeloma spinal involvement. This is of paramount importance for these patients, requiring often a high number of levels to be treated during the course of their disease and delaying their oncological pathway. We found this procedure easy to perform, and we did not experience complications in our preliminary results with this technique.

Conclusion

In this paper, we describe the clinical use of an easily reproducible, safe and efficient technique in patients undergoing multilevel vertebroplasty for MM with diffuse spinal involvement. In our opinion, the technique reduces the risk of fat embolism, allowing an increase in the amount of cement injected in a single-stage surgery, thus raising the number of levels treated in a single-stage and reducing the number of operations needed for treatment of multilevel disease. Further studies with a larger number of patients are needed to assess the efficacy and safety of the technique and the impact on the outcome.

Compliance with ethical standards

Conflict of interest None of the authors has any potential conflict of interest.

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