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ORIGINAL ARTICLE

Short segment pedicle screw instrumentation and augmentation vertebroplasty in lumbar burst fractures: an experience

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Abstract To assess the efficacy and feasibility of vertebroplasty and posterior short-segment pedicle screw fixation for the treatment of traumatic lumbar burst fractures. Short-segment pedicle screw instrumentation is a well described technique to reduce and stabilize thoracic and lumbar spine fractures. It is relatively a easy procedure but can only indirectly reduce a fractured vertebral body, and the means of augmenting the anterior column are limited. Hardware failure and a loss of reduction are recognized complications caused by insufficient anterior column support. Patients with traumatic lumbar burst fractures without neurologic deficits were included. After a short segment posterior reduction and fixation, bilateral transpedicular reduction of the endplate was performed using a balloon, and polymethyl methacrylate cement was injected. Pre-operative and post-operative central and anterior heights were assessed with radiographs and MRI. Sixteen patients underwent this procedure, and a substantial reduction of the endplates could be achieved with the technique. All patients recovered uneventfully, and the neurologic examination revealed no deficits. The post-operative radiographs and magnetic resonance images demonstrated a good fracture reduction and filling of the bone defect without unwarranted bone displacement. The central and anterior height of the vertebral body could be restored to 72 and 82% of the estimated intact height, respectively. Complications were cement leakage in three cases without clinical implications and one superficial wound infection. Posterior short-segment pedicle fixation in conjunction with balloon vertebroplasty seems to be a feasible option in the management of lumbar burst fractures, thereby addressing all the three columns through a single approach. Although cement leakage occurred but had no clinical consequences or neurological deficit.

Keywords Burst fractures · Spinal trauma · Pedicle screw · Kyphoplasty · Bone cement

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Introduction

Spine injuries is a serious medical condition that has a major impact on the quality of life of the patient [1, 2]. Although there is a varying consensus among treating physicians, surgical fixation of a traumatic fracture of the thoracic or lumbar spine is considered necessary if axial and rotational stability is severely impaired or if a neurologic deficit is present or imminent. Short-segment pedicle screw instrumentation is a well described technique to reduce and stabilize thoracic and lumbar spine fractures [3, 4]. It is a relatively easy procedure but can only indirectly reduce a fractured vertebral body, and the means of augmenting the anterior column are limited. Hardware failure and a loss of reduction are recognized complications caused by insufficient anterior column support [5–7]. Anterior procedures using iliac grafts or cages have been proposed to address the problem of this anterior column insufficiency, sometimes also in combination with posterior instrumentation. The anterior approach offers good visualization of the fracture and allows a direct restoration of the defect. Disadvantages compared with pedicle screw instrumentation are a longer duration of the procedure, higher blood loss, and an increase in postoperative morbidity [8–13]. Combined anterior/posterior approaches are major surgical undertakings for the patient and do not seem to provide any real advantages over the anterior procedure alone [9, 14–16]. Transpedicular spongiosaplasty, in which autologous bone grafts are impacted in the vertebral body through the pedicles after reduction to increase the stiffness of the anterior column, was developed and promoted by Daniaux in 1986 as an interesting addition to posterior surgery [17]. Recent studies have shown that this technique does not prevent the recurrence of kyphosis reliably and reproducibly [5, 18]. It has been noted by several authors that the loss of reduction after treatment of a fracture takes place mainly in the disc space. Previous studies suggest that intrusion of the disc through the fractured endplate into the weakened vertebral body, instead of degenerative disc changes, is the likely cause of this collapse [5, 19–22]. Preventing the disc intrusion by restoring the endplate anatomy after fracture reduction and fixation and filling of the resulting bone defect was the subject of a recent cadaveric study [23]. It was concluded in one of the studies by Verlaan et al. that anterior column augmentation by transpedicular balloon vertebroplasty with calcium phosphate cement (CPC) injection was safe and feasible [42]. Although both cements were suggested to be suitable vertebral bone void fillers, CPC showed superior biocompatibility, since the polymethyl methacrylate cement sometimes provoked a mild inflammatory reaction in the surrounding tissue [24, 25, 41]. The purpose of the present study was to demonstrate the feasibility and safety of balloon vertebroplasty with poly methylmethacrylate, in addition to posterior short-segment reduction and fixation in 16 patients with traumatic lumbar burst fractures.

Materials and methods

The clinical study proposal was approved by the medical ethical committee of the authors' institution. Patients with a recent burst fracture of the lumbar spine without neurologic deficits were included [26]. The study consisted of 12 male and four female patients (age, 22–53 years) with burst fractures resulting from a fall from height in 14(87%) or a motor vehicle accident in 3(13%) were included in the study. The affected levels were L1 (4), L2 (7), L3 (3), and L4 (2). The injuries accompanying were, Calcaneal fractures in three patients, distal radius fracture in three patients (Table 1). Patients with a rupture of the posterior longitudinal ligament on MRI, a Glasgow coma scale less than 15 at admission, and pre-existent pathology that could compromise the surgical procedure were excluded. Preoperative anteroposterior and lateral radiographs of the fractured spine were obtained as well as MRI scans (sagittal and transverse; T1 and T2 weighted for assessment of damage to the endplate, vertebral body, and discoligamentous structures. All patients were made to sign an informed consent after being informed about the procedure. The patients were operated as a priority at the earliest rather than an emergency basis. The steps of the procedure were followed as described by Verlaan et al. [42]). Short-segment pedicle screw-and-rod reduction and fixation under general anaesthesia and antibiotic prophylaxis was performed in all in order to realign the adjacent motion segments. After identifying, the pedicles of the fractured vertebral body were probed. Two cannulas were inserted into each pedicle under fluoroscopic guidance and placed with the tips just ventral to the posterior wall in the vertebral body. A space was created under the impressed endplate by a hand drill for the inflatable bone tamps to be introduced through the cannulas into the fractured vertebral body. After positioning the balloons with fluoroscopic guidance under the most impressed part of the endplate, the bone tamps were inflated simultaneously with 1-mL increments of contrast fluid under direct visualisation of fluoroscopic image to assess the amount of reduction, while the pressure on the digital pressure on the syringe was observed. Subsequent individual inflation of the bone tamps allowed some of the endplate reduction. The amount of poly methyl methacrylate cement needed to fill the resulting defect in the vertebral body was estimated from the total balloon volume and prepared as per the instructions of the manufacturer. The balloons were actively deflated and removed, and the reduced state of the endplates was monitored carefully. The cement was slowly injected under fluoroscopy to monitor the distribution. The cannulas were removed after completion. Pedicle screw and rod instrumentation was done one level above and one level below in all the cases and posterolateral fusion done using bone graft from the Iliac crest of the patient. A neurologic examination was performed soon after patient recovered from anaesthesia. The patients were immobilised in bed in a supine position for at least 24 h. The patients were mobilized wearing removable plastic jackets from the third day after surgery, and radiographs anteroposterior and lateral, were obtained to evaluate the reduction of the fracture, the distribution of the cement, and or any possible complications. At discharge, patients were encouraged to resume their daily routine but advised to wear the jacket for 8 weeks. One month after surgery, patients were assessed for any neurologic complications, and underwent an MRI examination. Pre- and post-operative Cobb angles were measured on the lateral radiographs. The central and anterior vertebral body height was measured on the mid-sagittal magnetic resonance images. The fractured and restored heights were calculated as a percentage of the estimated, intact vertebral body height by averaging the respective central and anterior heights from the adjacent levels. The MR images were also used to evaluate a possible bone displacement towards the spinal canal.

Table 1 Patient characteristics

Case	Age	Gender	Level	Classification Denis	Accompanying injuries	Cause
1	30	M	L3	Type B	None	Fall from height
2	34	M	L1	Type B	Cal.#	Fall from height
3	26	M	L1	Type C	None	Fall from height
4	38	M	L3	Type B	None	Fall from height
5	30	F	L3	Type B	Cal.#	Fall from height
6	22	M	L2	Type B	None	Motor vehicle accident
7	26	M	L2	Type C	None	Fall from height
8	29	F	L1	Type B	#Distal radius	Fall from height
9	47	F	L4	Type B	None	Fall from height
10	53	F	L4	Type C	#Distal radius	Fall from height
11	42	M	L1	Type B	None	Fall from height
12	28	M	L2	Type B	None	Motor vehicle accident
13	25	M	L2	Type B	None	Fall from height
14	50	M	L2	Type C	#Distal radius	Fall from height
15	24	M	L2	Type B	None	Fall from height
16	25	M	L2	Type B	None	Fall from height

Differences between the pre-operative and post-operative segmental kyphosis angles and vertebral body heights were analysed.

Results

No complications of instrumentation were seen, and following reduction, effective canal clearance was observed in all the patients. The peak pressure in the balloons varied from 35 to 120 psi with a mean maximum pressure of 77 psi after "setting", in which phase the balloon actually expanded and reduced the endplate. In all cases, substantial reduction of the fractured endplates was achieved with the bone tamps. The total amount of injected PMM varied from 10 to 27 g. The median duration of the total procedure was 142 min (range 92–190 min), and the median blood loss was 730 mL (500–2,000 mL) (Table 2). In all patients, the post-operative radiographs and MR images demonstrated a good position of the pedicle screw construct and the PMM in the fractured vertebral body. Cement leakage, was defined as any cement which was out of the confines of the vertebral body, observed on the postoperative radiographs and MR images in three patients; two patients had in the spinal canal, and one patient had in the caudal disc space. The presence of cement in the spinal canal well as in the caudal disc space was observed during surgery in both the cases and thus limited the further injection of PMM in these cases, and the spinal canal was cleared of the PMM immediately and thoroughly washed with saline. All patients recovered uneventfully, and the neurologic examination revealed no deficits. In one case, there was a superficial wound infection which was observed on third post operative day that resolved with antibiotics and daily dressing changes. The average Kyphosis angle before surgery was 9.4° (range 10.2–13.2, SD 9.1) and −1.8° after surgery, range, (−18.7 to 12.9° SD 9.4). The average central vertebral body height increased at an average from 67% before surgery to 83% of the estimated intact central height after surgery. The average anterior vertebral body height increased from 71% before surgery to 90% of the estimated intact anterior height after surgery. Both the kyphosis angle correction and the central and anterior vertebral body height gains were highly significant ($P < 0.0001$) Table 3. No posterior bone displacement was seen in any patient following the instrumentation and balloon vertebroplasty. The patients were followed for an average of 22 months (range 16–38 months). The procedure required approximately 27 min of extra operation time. Bleeding from the vertebra stopped as soon as the balloons were inflated and did not interfere with cement injection. We feel as well as noted by vernal et al. that immediate removal of the cannulas result in backward leakage of cement out of the pedicles, possibly caused by the exerted pressure of the intervertebral disc, and hence removed the cannulas just before closing the wound after we experienced cement leakage in the spinal canal in two of the cases, allowing a bit more time for the cement to set from a paste into a more solid state.

Table 2 Surgical details

Duration	Average 142 min (92–190 min)
Blood loss	Average 730 mL (500–2,000 mL)
Balloon pressure	Average 77 psi (35–120 psi)
Polymethyl methacrylate	10–27 g

Table 3 Percentage of central and anterior height

Anterior height	
Pre-operative	Average: 71% (range 49–98%)
Post-operative	Average: 90% (range 80–100%)
Central height	
Pre-operative	Average: 67% (range 46–90%)
Post-operative	Average: 83% (range 63–96%)

Discussion

In this study, we were able to demonstrate to some extent the feasibility and relative safety of this technique to directly reduce the fractured vertebral body and reinforce the anterior column after posterior indirect reduction and stabilization. Several studies have been conducted to assess the strength and stiffness of vertebral compression fractures after vertebroplasty with polymethyl methacrylate cement and CPC [27–31, 40]. In the cadaveric biomechanical study by Mermelstein et al. they found that the injection of CPC in a burst fracture reduced the load on the pedicle screw construct that was inserted for fracture stabilization [32]. It was concluded by them that vertebroplasty with CPC after posterior instrumentation might reduce hardware failure and anterior column collapse and decrease the need for a secondary anterior approach. As proposed by some authors that the fractured and impressed endplate increases the chance of intrusion of the intervertebral disc in the corpus which can cause subsequent spine deformity [19, 21]. The possibilities of vertebroplasty to reduce the endplate impression are limited and can only be achieved by building pressure on the cement, which is strongly associated with an increase in cement leakage that can result in spinal cord compression and pulmonary embolism [33–35]. The use of inflatable bone tamps in the treatment of osteoporotic compression fractures has received a lot of attention the last few years [36–38, 42]. This procedure was basically invented primarily to correct the deformity by lifting the compressed part of the vertebra to a more physiologic position before polymethyl methacrylate cement injection. As has been observed by various authors during inflation, the balloons push aside intravertebral cancellous bone, it around them and thus resulting in a layer of higher-density bone, which in turn lines the cavity in which the cement is to be injected. To decrease the chance of cement leakage due to the presence of a cavity that allows for a lower injection pressure, this bone lining may act as a shield. However in practice it seems, the number of cases with cement leakage is considerably lower for balloon vertebroplasty than for conventional vertebroplasty [39, 42]. As demonstrated by Verlaan et al. [42] reduction of the fracture by ligamentotaxis before performing balloon vertebroplasty might also decrease the risk of cement leakage due to the resulting alignment of cortical bone fragments. In their study, they have demonstrated that the inflatable bone tamps were used for yet another purpose besides creating a lined cavity. We also followed the same principles, thereby reducing the incidence of cement leakage. As the studies [19, 20, 42] have demonstrated that the recurrent kyphosis is the result of a change in the disc space morphology, hence we also aimed to reduce the endplate fracture directly with the balloons, thereby restoring the morphology of the disc space [19]. In one of the cadaveric studies, it has been demonstrated to be feasible and safe to reduce the endplate in burst fractures after pedicle screw stabilization [23]. As described by others it is not possible to achieve an anatomic reduction because the balloons cannot always be positioned under the most depressed, often central, part of the endplate, and also probably because partial loss of hydrostatic counter pressure of the adjacent intervertebral disc. We chose PMM cement because it has been used for vertebroplasties in osteoporotic fractures since long with known biocompatibility and the availability of it. We followed the patients for a longer period to detect any immediate complication from the surgical procedure. Potential hazards included retropulsion of bone fragments following balloon expansion, extracorporal cement leakage resulting in pulmonary embolism, or spinal cord compression and infection. We had complications as mentioned above but did not come across any of the major complications. We feel our complications were because of the lack of knowledge about the procedure as can be explained by the fact that our complications occurred in the initial cases, thus emphasising the delicacy and complete knowledge of the procedure and also the biomechanical aspects of the cement vertebroplasties.

As our series is not a big one, but with a long enough follow up, we feel this procedure can be applied, however further studies with a larger series are required to demonstrate whether this technique can prevent the complications like late segmental kyphosis and other unforeseen complications, and can help to further advance the technique.

Conclusion

This procedure seems feasible in combination with posterior instrumentation, taking care of all the three columns through one approach. The additional part of the procedure is not so demanding, and time consuming. Although there were complications, but did not have a clinical implications. This procedure has a potential to avoid anterior surgery for lumbar burst fractures.

Conflicts of interest No benefits in any form have been received or will be received from any commercial party related directly or indirectly to the subject of this article.

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