Percutaneous augmented instrumentation of unstable thoracolumbar burst fractures

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Abstract

Background Internal fixation of unstable thoracolumbar spine fractures requires correction of the lacking anterior column support. This usually entails insertion of a vertebral body replacement strut through an anterior approach, or a long posterior construct spanning at least two vertebrae above and two vertebrae below the fracture. Posterior short-segment pedicle instrumentation (SSPI)—one vertebra above and below—is suitable for approximately 40% of fractures, but not for all.

Methods A total of 52 patients with unstable thoracolumbar burst fractures meeting our inclusion criteria were

instrumented using a novel approach, combining percutaneous SSPI, pedicle screw augmentation with polymethyl methacrylate (PMMA) and fractured vertebra kyphoplasty. We retrospectively reviewed patient and fracture data, operative results and 1 year radiographic follow-up post-operatively in 40 of the patients. We reviewed operative complications of all 52 patients.

Results Most fractures were AO/Magerl type A3.1, A3.2 and A3.3. They were instrumented within 72 h and ambulated without additional external bracing. Operative time averaged 2 h and blood loss was less than 50 cc in most cases. Complications were mostly related to PMMA leakage. On average, 3.3° (0–13) of correction was lost after 3 months, but remained constant afterward.

Conclusions Percutaneous augmented short-segment pedicle instrumentation of unstable thoracolumbar fractures can be done with short operative times, minimal blood loss and a low complication rate. The radiographical results at 1 year are equal to anterior stabilization and are better than other posterior-only techniques.

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Introduction

Internal fixation of unstable thoracolumbar spine fractures usually requires correction of the lacking anterior vertebral column support [1]. This is done to prevent the spine from collapsing into kyphotic deformity, and can be achieved either directly through an anterior approach or indirectly by implantation of a long posterior construct instrumenting 2–3 vertebrae cranial to the fracture with two vertebrae caudal to it. Each of these approaches requires extensive

exposure of the spine, with prolonged operative times and profuse intraoperative blood loss [1–4].

Short-segment pedicle instrumentation (SSPI) is an attractive solution for fast stabilization of vertebral fractures, instrumenting only one vertebra above with one vertebra below the fracture. It can be done in some cases percutaneously in less than 1 h, involves minimal blood loss, and can enable early patient mobilization. Unfortunately, initial results with SSPI were dismal, with failure of the fixation in up to 50% of patients if not pre-selected [4]. On the other hand, pre-selection according to fracture stability eliminates about 40% of the potential patients from receiving SSPI, these being typically the most severely injured [5].

In the past decade, vertebroplasty and kyphoplasty—vertebral augmentation with polymethyl methacrylate (PMMA)—have gained widespread use in the treatment of osteoporotic compression fractures and in preventing pedicle screw pullout from osteoporotic bone.

A few recent publications [6–11] have combined SSPI with fractured vertebra augmentation, yielding encouraging preliminary results in osteoporotic and younger patients with normal bone stock. All of these studies have been done through an open technique, or by combining percutaneous SSPI with kyphoplasty only. We would like to describe our experience with a novel approach, combining all three elements: (1) percutaneous SSPI of one vertebra cranial and one vertebra caudal to the fracture; (2) balloon kyphoplasty of the fractured vertebra; (3) augmentation of the pedicle screws with PMMA.

Patients and methods

This study was approved by our institution's medical ethics committee. A total of 52 consecutive patients meeting our inclusion criteria and presenting at our emergency department over a 22-month period were retrospectively reviewed.

Inclusion criteria were: (1) one unstable thoracolumbar fracture; (2) intact neurologically; (3) no other significant injury.

All surgeries were done by one or more of three of the authors (N.R, S.F or M.H) within 72 h of arrival at the hospital, according to a predetermined surgical protocol, consisting of general anesthesia, prone positioning on two silicone padded rolls providing chest and pelvic support, percutaneous SSPI (Sextant, Medtronic, USA), pedicle screw augmentation with PMMA (Confidence, Disc-o-tech, Israel or Kyphex, Medtronic, USA) and balloon kyphoplasty (Kyphon/Medtronic, USA).

Radiographic evaluation (Figs. 1, 2) included supine admission radiographs and CT scan, day 1 or 2 postoperative

standing radiographs, and 3 and 12 months follow-up standing radiographs.

The fractures were classified according to the AO/Magerl classification [12] and were measured for kyphotic deformity at the fracture level (Gardner angle).

Results

A total of 12 patients were excluded from the study, leaving 40 for subsequent follow-up. Patients were excluded because of the following: the surgeon deviated from the above-described surgical technique ($N = 5$); it was subsequently found that they had metastatic involvement of the fractured vertebra ($N = 4$); they were lost to follow-up ($N = 3$).

Of our patients, 12 were male and 28 were female. The average age was 56.8 years (16–88, five patients below 40 years), and the average weight was 74.2 kg (60–90 kg).

Most fractures were at the thoracolumbar junction (Table 1) and most were type A3.1, A3.2 and A3.3 according to the AO-Magerl classification [12] (Table 2).

The average operative time was 121 min (64–188), and the estimated intraoperative blood loss was less than 50 cc in 31 (77.5%) patients (Table 3). Data were incomplete in six cases, but in 34 we found that the average preoperative Hb was 12.8 gr%, while the postoperative was 11.9. The Hct changed from 37.37 to 34.6, respectively.

All of the instrumentations were considered stable, and most of the patients ($N = 33/82.5\%$) were assisted out of

Fig. 1 Supine preoperative sagittal CT reconstruction demonstrating a 23° segmental kyphosis

Fig. 2 Standing post-operative lateral film demonstrating correction of the segmental kyphosis in Fig. 1 to 6°

Table 1 Fracture level distribution

Fracture level	N
T6	1
T10	1
T12	7
L1	19
L2	8
L3	3
L4	1

Table 2 Fracture types and numbers according to the AO/Magerl classification

A1.3	A2.2	A2.3	A3.1	A3.2	A3.3	B2.1
1	2	1	10	11	14	1

Table 3 Estimated blood loss (EBL) during surgery and on the first postoperative day (POD1)

EBL	Intraoperative	POD 1
0	0	31 (77.5%)
0–50	31 (77.5%)	7 (17.5%)
50–100	2 (5%)	0
Over 100	1 (2.5%)	0
Undocumented	6 (15%)	2 (5%)

Table 4 Loss of reduction over time when compared with the first postoperative standing films

Time from surgery	N	Degrees	Range	SD
Up to 3 months	29	3.5	0–13	3.17
More than 12 months	13	3.05	0.5–10.1	2.38
Overall	35	3.3	0–13	3.11

When serial radiographs were obtained, reduction loss was observed only during the first 3 months

Table 5 Procedure-related complications observed in all 52 patients

Complication	N
PMMA leak: fractured vertebra	16
PMMA leak: intact vertebra	34
PMMA emboli	3
CSF leakage	1
Infections (superficial)	1
Neurological loss	0

bed and encouraged to ambulate on the first postoperative day. Six (15%) were mobilized on the second postoperative day, and one much later due to associated injuries. Bracing or any other external support was not used.

All of the patients were asked to return to our outpatient clinic after 3 months and 1 year for follow-up standing films. Overall, follow-up was achieved in 35 patients. The remaining five patients were interviewed by phone.

Radiographic follow-up demonstrated an average of 3.3° loss of correction after 1 year when compared with the immediate postoperative standing films. This loss of correction was found to occur during the first 3 months and remained virtually unchanged in the following months (Table 4).

The surgical complications found are summarized in Table 5. Virtually all cemented vertebrae leaked, but in three different ways. The fractured vertebrae tended to leak through fracture line to the adjacent soft tissue, while the intact vertebrae leaked to the segmental veins. A third form of leakage was PMMA emboli to the pulmonary artery, presumably ascending via the segmental veins to the inferior vena cava. No leaks were seen in the spinal canal.

We had one case of superficial wound infection at one of the incisions with methicillin-sensitive *Staphylococcus aureus*. This was treated by suture removal, drainage and IV antibiotics for 3 weeks.

Four of our female patients died during the 22-month study period. Two patients (86 and 71 years old) died of unrelated causes many months after surgery, one 72-year-old died of complications following hip fracture surgery done 17 months after the spine surgery, and one 60-year-old patient with known ischemic heart disease died of

inferior wall myocardial infarction 1 week after surgery. All males were still alive at the 22-month mark.

Discussion

Percutaneous augmented instrumentation (PAI) is a combination of three surgical techniques: SSPI, kyphoplasty and pedicle screw augmentation. We have used it for early surgical stabilization of unstable AO type of A3 fractures, which, otherwise, would have required prolonged conservative treatment or extensive surgery.

Our operative time averaged 2 h, but this probably reflects the learning curve of three surgeons. After the technique is mastered, surgical times are usually just over 1 h. Intraoperative bleeding is typically less than 50 cc, which compares very favorably with open posterior thoracolumbar fracture fixation where the expected blood loss is at least tenfold [13, 14].

Percutaneous augmented instrumentation is a non-fusion technique (no bone graft is used); therefore, after the fracture has healed, the instrumentation can be removed and motion restored to the instrumented levels. This is of value also at the initial surgery, reducing operative times and possible complications associated with bone graft harvest and donor site morbidity.

Certain concerns arise from this technique. The first is the risk of PMMA leakage through the fracture lines into the spinal canal or to adjacent soft tissue. Since PMMA tends to flow to the area of least resistance, creating a cavity within the fractured vertebra enables low-pressure injection, thus theoretically reducing this risk. Another precautionary measure is continuous pulsed fluoroscopy during cementation. If the PMMA seems to be nearing the posterior vertebral cortex, further injection is aborted.

The second concern is PMMA emboli. PMMA can leak through segmental veins into the inferior vena cava and reach the lungs. This is a well-known complication of vertebroplasty [15, 16]; yet, alarming as it may seem, it is usually sub-clinical with very rare short- or long-term implications [15]. If routine chest CT scanning is done after the procedure, 23% of vertebroplasty patients are found to have pulmonary PMMA emboli [16], apparently with no sequelae.

A third concern pertains to the use of PMMA in younger patients. PMMA has been used in orthopedic surgery for over half a century in almost all bones and has shown minimal adverse side effects, usually related to prosthesis loosening and particle wear, and not the PMMA itself [17]. While in older patients, we are confident no adverse consequence will develop during the rest of their life expectancy, no long-term follow-up study has yet been published on younger patients. Only five patients in our series were

below the age of 40 years, but their results are virtually identical to the above 40 years age group. In three of these cases and in recent cases (performed after the end of this study), we have opted for tricalcium-phosphate cement as the bone filler in patients younger than 40 years, assuming it to be a more “biologic” solution, although there has been no long-term follow-up in the literature for this choice either.

Augmentation of the screws in the intact vertebrae is an important component of this technique, since it is very effective in preventing pullout. Biomechanical studies have demonstrated that screw augmentation will increase pullout loads in osteoporotic bone to almost 1.5 times that of normal, non-porotic controls [18]. On the other hand, fractures in younger patients are very different from those in the elderly and should generally be considered separately. Since augmenting the intact vertebrae of a healthy 22-year-old might be an overkill, kyphoplasty of the fractured vertebra along with a non-augmented short-segment posterior instrumentation might be sufficient in this subset [19]. Another alternative to PMMA cementation in percutaneous instrumentation is to instrument more levels [20], omitting the use of bone cement altogether.

As PAI is a relatively new technique, with very little published evidence delineating the scope of applicability in clinical practice, our study was formed to explore its boundaries for future use. This small series is not powered enough to resolve this issue, and larger studies are required to form precise clinical indications.

Conclusion

Percutaneous augmented instrumentation is a stabilization method for unstable thoracolumbar spine fractures, which enables early mobilization of severely injured patients with minimal surgery. We believe it improves our ability to care for trauma patients, replacing in many cases extensive open surgery and reducing related complications.

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Conflict of interest None.

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