Helmut Franck
Bronek M. Boszczyk
Michael Bierschneider
Hans Jaksche

Interdisciplinary approach to balloon kyphoplasty in the treatment of osteoporotic vertebral compression fractures

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H. Franck (✉)
Center of Rheumatology,
Hubertusstr. 40 Oberammergau,
82487 Oberammergau, Germany
Tel.: +49-8822-914261,
Fax: +49-8822-914222,
e-mail: hfranck@wz-kliniken.de

B. M. Boszczyk · M. Bierschneider
H. Jaksche
Department of Neurosurgery,
Berufsgenossenschaftliche Unfallklinik
Murnau, Prof. Küntscher Str.8,
D-82418 Murnau, Germany

Abstract Osteoporotic vertebral compression fractures (VCFs) are associated with a series of clinical consequences leading to increased morbidity and even mortality. Early diagnosis and therapeutic intervention is desirable in order to remobilise patients and prevent further bone loss. Not all fractures are, however, sufficiently treatable by conservative measures. Here, vertebroplasty and kyphoplasty may provide immediate pain relief by minimally invasive fracture stabilisation. In cases of acute fractures, kyphoplasty has the potential to reduce kyphosis and restore the normal sagittal alignment of

the spine. The complex nature of systemic osteoporosis, coupled with the intricate biomechanics of vertebral fractures, leads to a clinical setting which is ideally treated interdisciplinarily by the rheumatologist and spine surgeon.

Keywords Vertebral compression fracture · Osteoporosis · Kyphoplasty · Vertebroplasty

Introduction

Osteoporotic vertebral compression fractures (VCFs) are the most common type of fracture, followed by hip fractures. The incidence rate is 117 per 100,000 persons per year, but it accounts for 41,000 hospitalizations per year, with an average length of stay of 20 days [7, 10]. The European Commission estimates hospital expenditures in Europe to be greater than 340,000,000 Euro (almost 1,000 Euro per day) [10].

This economic burden [10] is partly the result of progressive kyphosis and chronic pain, often leading to significant morbidity in the elderly individual [19]. Pain can be caused by nociceptors in bone itself, the disc complex, the perivertebral structures, through nerve compression, joint or muscle pain. Although the majority of patients with this injury experience a benign and self-limited course of gradually resolving pain, a significant number continue to experience chronic pain, progressive kyphosis and disability. Long-term consequences include significantly de-

creased activities of daily living (ADL) amounting to five million limited activity days in the U.S. [28]. As a consequence, patients suffer from an increased dependence on others, sleeping disorders and clinical anxiety, including reduced mobility [13, 32]. Furthermore, VCF symptoms and consequent treatments may include overall inactivity, which leads to further bone loss and potential fracture. Patients treated for sleeping disorders with sedatives are less astute, which puts the patient at risk for falls. Decreased ADL with dependence on others further reduces the necessary activity level and strain on bone for healing processes [23]. Malnutrition from early satiety due to a compressed stomach results in poor calcium intake [32]. Finally, hyperkyphotic patients are at risk of reduced pulmonary function [30].

Diagnosis

VCF diagnosis requires a detailed history and physical examination. Investigations should be aimed at excluding

other causes of back pain. In evaluating such a patient, the differential diagnosis must consider not only osteoporosis but also various causes of osteomalacia, endocrinopathy and malignancy. Sometimes further diagnostic tests, including psychology, physiotherapy and various medical specialities, are necessary to substantiate the need for therapeutic intervention. Magnetic resonance imaging is often helpful in excluding other causes of pathologic fracture and in distinguishing fresh from older fractures. For the latter, the STIR (Short Tau Inversion Recovery) imaging technique should be employed, which is very sensitive for osseous edema following a vertebral fracture.

High-risk patients need special attention. Patients with one or more vertebral fractures are five times more likely to have an additional VCF within the next year [22]. Some patients with secondary osteoporosis have multiple risk factors. In patients with rheumatoid arthritis, the inflammatory process itself, the physical inactivity and the necessary treatment with glucocorticoids also enhances the incidence of osteoporosis. These patients show a reduced bone volume and decreased bone turnover, which is further aggravated by microarchitectural deterioration stressing the severe osteoporosis associated with the disease. As a consequence, subjects with rheumatoid arthritis have reduced bone mineral density and at least a twofold increased risk of osteoporotic fractures [25].

Treatment options

An interdisciplinary approach is substantial not only in diagnostic, but also in therapeutic strategies. The aim of treatment of osteoporosis is to halt bone loss, to reduce pain and to prevent the occurrence of future fractures through osteoinduction. Pharmacological treatments for bone loss include the bisphosphonates, hormone replacement therapy, selective oestrogen receptor modulators, calcitonin, the 1–34 fragment of parathyroid hormone, calcium and vitamin D supplements, and calcitriol. Long acting strategies for patients with secondary osteoporosis must include effective treatment of the primary disease. In rheumatoid arthritis, this aims to reduce risk factors by inhibiting inflammatory activities of the disease by avoiding glucocorticoids and applying physical therapy.

However, these medications for osteoporosis alone cannot inhibit or reduce pain instantly or completely. Consequently, a conventional treatment for pain reduction including the WHO recommendations of staged pain treatment is necessary. Drugs for the treatment of pain should be prescribed cautiously if the drugs have side effects on the central nervous system that could potentially lead to falls.

Traditional treatment for these patients includes bed rest, analgesics and bracing, all of which are aimed toward pain management and remobilisation; however, none of these strategies address the immediate treatment of the lo-

cal mechanical problem associated with the fracture itself. Furthermore, in most cases, early remobilisation is not initiated. Bed rest exasperates further bone loss, therefore increasing the risk of further fractures [14]. Lifestyle changes should also be encouraged in high-risk patients. Physical exercise is necessary, which includes site specific and weight-bearing loading, including muscle resistance. It should be performed two to three times per week, exceeding the normal daily loading with peak forces.

Interventional treatment options

With failure of conservative treatment, operative stabilisation should be considered. As vertebral fractures are biomechanically complex and surgical strategies vary according to the fracture type [24], the evaluation of the patient for surgery is ideally done in an interdisciplinary manner together with a spine surgeon. While taking the underlying medical condition into consideration, the surgeon's main focus is on the character of the fracture. Conventional reconstructive procedures involving implants are generally not a suitable option for this elderly population due to the poor bone quality and the reduced tolerance of operative trauma. Vertebroplasty and kyphoplasty pose minimally invasive alternatives for the direct stabilisation of the fracture. Both techniques may be performed under general or local anaesthesia using CT or biplanar fluoroscopy. The technique of vertebroplasty is well described in the literature [17]. Briefly, a needle (usually a bone biopsy needle) is percutaneously introduced into the affected vertebral body via a transpedicular or extrapedicular approach. Bone cement, polymethylmethacrylate (PMMA), is then injected directly into the vertebral body at moderate to high pressure at low viscosity in order to achieve trabecular filling. The fracture is stabilised once the PMMA is cured. Kyphoplasty employs the same approaches as vertebroplasty; however, working cannulae are bilaterally passed over initially placed guide pins and obturators, which allows inflatable balloons to be placed in the vertebral body (for detailed technique see Garfin et al. [11]). The balloon is slowly inflated under fluoroscopic guidance while carefully monitoring the balloon positioning in relation to the cortices. Once maximum fracture reduction and height restoration are achieved, both balloons are deflated and removed, leaving behind a defined cavity, which is then manually filled under low pressure with highly viscous, radiopaque PMMA cement. The dosage is regulated according to the end volume of the inflated balloon as noted on the inflation syringe. Biomechanically, both procedures are very efficient in restoring vertebral strength, both with regard to ultimate compressive strength [1, 36] and under cyclic loading [35]. As pain relief is similarly efficient for both procedures [11, 17], the choice of technique involves several factors.

Spinal deformity

The sagittal balance of the spine should be taken into account. As suggested by Keller et al. [20] in an example of a vertebral deformity model, kyphotic deformity in excess of 10° at T7 and T8 produces 15.1-cm anterior translation of the cervicothoracic spine with an increase of 19% compressive force and 40% increase in paraspinal extensor muscle force at these levels. While vertebroplasty essentially “freezes” the deformity, kyphoplasty has been found to reduce segmental kyphosis on average by 6–18° [11]. In fresh fractures, reduction reaches an average of 14° [11], with the possibility of near complete height restoration in the acute setting [4]. While vertebroplasty is an efficient stabilisation method when deformity is not of concern, kyphoplasty should be considered for fractures with kyphotic deformity, especially when treating acute fractures.

Fracture type

As vertebral augmentation procedures do not address flexion or rotation instability, the work-up of the patient should involve fracture classification according to Magerl et al. [24] in order to rule out type B and C injuries. When there is a doubt as to the fracture type, MRI should be performed to assess any injury of the discoligamentary structures. In type B or C injuries, posterior instrumentation remains a necessity. The vast majority of spontaneous fractures will be of the A1 type; however, more complex fractures can occur in trauma settings, e.g. from falling down stairs, off a bicycle or in motor vehicle accidents, as may occur infrequently in the more active, younger rheumatoid patients with secondary osteoporosis. Furthermore, assessment of the fracture type involves the fracture morphology of the vertebral body. Depending upon the degree of trabecular bone loss, failure of a severely osteoporotic vertebral body may result in complete collapse without significant fragmentation (type A1.3), while vertebral shattering (incomplete burst type A3.1, split burst type A3.2 and complete burst fracture type A3.3) generally occurs in less osteoporotic vertebra. The former fracture type is more common in the elderly patient with primary osteoporosis and is treatable by kyphoplasty, while the latter more often occurs in the younger patient with secondary osteoporosis in a trauma setting. These fractures must be evaluated carefully, as kyphoplasty in type A3.3 complete burst fractures may result in separation of the fragments rather than cavity formation if the osteoporosis is only mild. Although there is a theoretical risk of bone retropulsion through kyphoplasty in burst fractures, anterior placement of the balloon usually prevents expansion towards the posterior wall during inflation. Incomplete burst fractures of the type A3.1 have been treated successfully [4]. When treating burst fractures, the fissures in the posterior

vertebral wall increase the risk of epidural cement leakage for all augmentation procedures, but especially for vertebroplasty due to the injection of PMMA at low viscosity and moderate to high pressure. Here, kyphoplasty increases operative safety, as PMMA is injected at high viscosity and low pressure into the cavity created during balloon inflation. Although minor leakage does not usually result in neurological impairment, several cases of severe neurological deficit and systemic embolism following vertebroplasty have been documented [2, 6, 15, 18, 21, 26, 27, 31, 33].

The potential for serious complications, however rare, require scrupulous intraoperative fluoroscopic monitoring for bone retropulsion or cement leakage and provisions should be made for potential conversion to open surgery and embolism management.

Neurological deficit

Severe vertebral collapse or posterior wall fragmentation, although rare, is able to induce neurological deficit due to nerve root compression. As neural decompression cannot be undertaken percutaneously, surgical decompression is required in addition to vertebral augmentation. Bilateral open decompression with transpedicular vertebroplasty and interlaminar microsurgical kyphoplasty have been described for the treatment of these severe fractures [34, 5].

Uncomplicated percutaneous vertebroplasty can usually be accomplished in approximately 15 min for a single level. For the same indication Kyphoplasty will need an additional 10–15 min. However, in fractures involving significant height loss, kyphotic deformity or fragmentation of the posterior vertebral wall, kyphoplasty should be considered despite the slightly prolonged operation time due to the potential for fracture reduction and lower cement leakage rate. Although the overall rate of serious complications is very low (under 2% in the kyphoplasty review by Garfin et al. [12]), precautions should be taken for the possibility of surgical decompression of the spinal canal, additional instrumentation and management of pulmonary embolism.

Post-operative management

Once the bone cement is cured, patients may be mobilised with full weight bearing. Application of an orthosis is not routinely recommended. While patients appear to benefit from this procedure, Kyphoplasty alone has not been shown to prevent further vertebral fractures. Hence, it is of utmost importance to inhibit the vertebral fracture rate in these patients. Pharmacotherapy should be continued for 2–3 years at least. Alendronat 10 mg/day or 70 mg/week [3], Raloxifen 60 mg/day [9] and Risedronat 5 mg/day [16] or 35 mg/week orally have been proven to reduce the

fracture rate in patients with prevalent fractures. Calcium 500 mg and Vitamin D 400–800 IE should be taken daily. These medications have been shown to have an evidence based medicine grade A. If these drugs are not tolerated well, other medical treatments are recommended. This includes calcitonine spray, etidronate intermittently, estrogen/gestagene, fluoride or active vitamin D metabolites. Lifestyle changes should also be continued as described, with physiotherapy going ahead. Patients should be monitored every 3–6 months.

Discussion

Osteoporotic VCFs present a significant economic burden to society and result in severe clinical consequences leading to impaired physical function, reduced pulmonary function and overall increase in mortality. Traditional medical options, including bed rest, analgesics and bracing, have proven to be insufficient. Furthermore, the problem of osteoporosis is underestimated and often not diagnosed [10]. Therefore, an interdisciplinary approach that addresses both the underlying disease and the local mechanical problem of the fracture itself is recommended.

Geriatric patients treated with kyphoplasty in combination with pharmacologic and physical therapy quickly return to higher activity levels, leading to increased independence and quality of life. However, while the principle is innovative, the procedure deserves further investigation as a potentially effective means of correcting loss of vertebral height. Further light will be shed on the efficacy of this procedure by a recently initiated randomised multicentre study comparing conservative and operative treatment. A remaining matter of debate is the number of levels that should be treated and whether to prophylactically include unfractured levels between vertebrae that need stabilisation. As yet, the clinical and biomechanical literature is inconclusive on this topic. As patients with preexisting osteoporotic fractures have been shown to have a highly increased risk of developing new fractures (factor 7 with two fractures, factor 17 with multiple fractures) [29], especially of the thoracolumbar junction [8], augmentation of vertebrae adjacent to fractures in this high-risk zone should be considered on an individual basis. Further interdisciplinary investigations conducted by rheumatologists and surgeons are needed to determine the ideal treatment strategy for these patients.

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