



VERTEBRAL CEMENT AUGMENTATION PROCEDURES: COMPARISON BETWEEN KYPHOPLASTY AND VERTEBROPLASTY

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ABSTRACT

Vertebral compression fractures (VCF) are painful conditions resulting either due to osteoporosis or tumor. These may result in acute pain around the fracture site, loss of vertebral height due to vertebral collapse, spinal instability and kyphotic deformity. When spinal fractures occur, treatment options are limited. Cement augmentation of painful osteoporotic compression fractures consists of percutaneous stabilization of the vertebral bodies with polymethylmethacrylate (PMMA). Percutaneous vertebroplasty (PV) and Kyphoplasty (PK) are two vertebral augmentation procedures that have emerged as minimally invasive surgical options to treat this condition. Vertebroplasty is characterized by the insertion of polymethyl methacrylate into the fractured vertebra; kyphoplasty uses an inflatable balloon to create vertebral body expansion before the injection of cement. The main aims of these procedures are immediate pain relief and restoration of vertebral height. This literature will provide a brief overview on the current scenario of these procedures and will compare the efficacy and safety of these two procedures.

Keywords: *kyphoplasty *vertebroplasty *cement *polymethylmethacrylate

INTRODUCTION

Percutaneous Vertebroplasty (PV) and kyphoplasty (PK) are two well-known percutaneous procedures effective in relieving pain caused by acute and sub-acute vertebral compression fracture (VCF). Previously, Decompression and Fusion was the only surgical option to treat VCFs. This used to fail often in the elderly patients due to osteopenia [1]. Vertebroplasty was initially described for the treatment of aggressive hemangioma of the lumbar spine. It is performed through a needle that is inserted via a transpedicular approach into the vertebral body. Liquid cement, which rapidly polymerizes, is installed under pressure to fill the fractured vertebral body. Improvement in kyphotic angulation, if any, is obtained by prone positioning in extension. Kyphoplasty attempts to reduce the wedge-shaped vertebra and thus improve kyphotic angulation by expansion of the compressed vertebral body using an inflatable balloon. After expansion of the vertebral body, cement augmentation is performed.

DISCUSSION (VERTEBROPLASTY vs. KYPHOPLASTY)

History:

Gakibert and Deramond, interventional neuroradiologists in France, first performed percutaneous vertebroplasty in 1984[2]. These physicians injected polymethylmethacrylate (PMMA) bone cement into C2 vertebra destroyed by painful vertebral hemangioma, and the patient's chronic pain was alleviated. Later on, PMMA, following a similar percutaneous technique, aided with fluoroscopic guidance, was injected into the vertebral body of vertebrae fractured by osteoporosis [3]. The technique became popular among radiologists and patients for rapid pain relief and over time was modified in terms of materials and methods to minimize the risk of extravasation, thereby increasing safety. However, vertebroplasty was not effective in restoring vertebral height. There were some other serious concerns associated with this particular technique: injecting bone-cement at high pressure into the vertebral body led to bolus embolization through the venous channel in the VB to the lungs, and bone cement extravasation through the spinal cord can lead to devastating neurological complications. As a solution to all these issues, kyphoplasty was introduced in the 1990s with the aim of stabilizing the vertebral fracture and restoring the vertebral height as close as possible to the pre-fracture level and minimizing the associated kyphotic deformity. Dr. Mark Reiley, an orthopedic surgeon, introduced the idea of inserting an inflatable balloon tamp into the VB to elevate or expand the vertebra to its original height. The extent of pain relief in PK is similar to PV. These 2 procedures differ mainly in the surgical techniques used. PV involves the injection of liquid PMMA into the closed space of a fractured vertebra, but PK first creates a cavity inside the vertebral body, followed by the controlled filling of the cavity with partially cured PMMA [4-6].

Indications and Contraindications of PV and PK:

The most common indication for cement augmentation is in patients with a painful osteoporotic compression fracture that fails to improve with time and nonsurgical management [7]. The time between fracture and the consideration of cement augmentation is controversial. Most authors suggest a minimum of 3 weeks of nonsurgical care; however, the usual duration of symptoms of an osteoporotic vertebral compression fracture is 2 to 3 months. A meta-analysis of randomized controlled trials (RCTs) showed excellent results in both early care (i.e., 2 to 3 weeks) and later care (i.e., 2 to 3 months) groups[8]. According to the guidelines published by the Society of Interventional Radiology (SIR) in 2003, the common indications for PV include osteoporotic VCF older than 2 weeks and refractory by medical therapy, painful vertebra with extensive osteolysis or invasion secondary to benign or malignant tumor, and painful vertebral fractures associated with osteonecrosis [9] . Other indications are in patients with painful primary bone tumors, such as aggressive hemangiomas and giant cell tumors, and lytic metastatic tumors with a pathologic fracture or a pending fracture. Cement augmentation has also been used in patients with painful nonunion of a vertebral fracture, also known as Kümmell disease [10] .

The absolute contraindications include asymptomatic vertebral body compression fractures, active osteomyelitis of the target vertebra, uncorrectable coagulopathy, allergy to bone cement, patient condition improving upon medical therapy, prophylaxis in osteoporotic patients, and myelopathy originating at the fracture level. There also remain several other relative contraindications. In 2009, the American College of Radiology (ACR), the American Society of Neuroradiology (ASNR), the Society of Neurointerventional Surgery (SNIS), the American Society of Spine Radiology (ASSR), and the Society of Interventional Radiology (SIR) collaboratively prepared the official practice guidelines for vertebroplasty [11]. The indications and contraindications for KP are similar to those for PV (table 1) .

Indications and Contraindications for Vertebroplasty and Kyphoplasty

Indications

- Painful osteoporotic VCF that does not improve with 2 to 3 weeks of nonsurgical care
- Patient hospitalized as a result of painful osteoporotic fracture
- Painful pathologic fracture
- Aggressive hemangioma of the spine
- Kümmell disease

Absolute Contraindications

- Asymptomatic fractures
- History of vertebral body osteomyelitis
- Allergy to bone fillers or opacification agents
- Irreversible coagulopathy

Relative Contraindications

- Presence of radiculopathy
- Bone retropulsion against neural structures
- Greater than 70% collapse of vertebral body height
- Multiple pathologic fractures
- Lack of surgical backup to manage potential complications

Table 1

Technical Aspects:

Confirmation that a new fracture is present should be established using MRI, bone scans, or serial imaging studies before considering cement augmentation. MRI can show fracture acuity and fracture pattern and can help identify an adjacent occult fracture. Bone scans can also be used to evaluate the acuity of an osteoporotic VCF; acute fractures tend to have increased uptake because of the high metabolic activity within the bone. This imaging modality has relatively high sensitivity but low specificity and can remain positive for >1 year after substantial healing has occurred. Therefore, MRI is the best imaging study to evaluate fracture chronicity.

Physical examination also plays an important role in diagnosing VCFs. Tenderness to palpation at a single level with non-tender adjacent segments and pain exacerbated by standing erect or with a change of position (i.e., mechanical symptoms) is characteristic findings associated with symptomatic VCFs [12, 13]. More recently, Postacchini et al [14] evaluated specific pain-related behavior in patients with osteoporotic VCFs. They found that pain-related behaviors (e.g. grimacing, sighing, and the need for help with positioning) correlated with having an acute VCF confirmed by MRI and were not present in normal control subjects.

Imaging plays an important role in the process of vertebral augmentation, especially fluoroscopy. Both PV and PK should be performed by a clinician with in-depth knowledge of spinal anatomy and fluoroscopy imaging. The spinal level of the patient is verified by preoperative imaging and image intensifier before placing any cannula or syringe. Real-time fluoroscopic imaging is used to monitor the proper advancement of the trocar and injection of bone cement into the fractured site of the VB to avoid extravasation of cement into the neighboring tissues. Biplanar or C-arm fluoroscopy is generally used to provide maximal safety. General anesthesia or monitored anesthesia is used. General anesthesia is the optimal choice for lengthy cases of multiple levels of vertebral fracture. In case of monitored anesthesia, the local anaesthesia should be injected generously, especially into the periosteum, as some patients feel discomfort during the advancement of the trocar through the posterior cortical margin with balloon inflation (in case of kyphoplasty) and with injection of bone cement .

A small incision is made to insert the 11-inch cannulated trocar and biopsy needle. The cannula is advanced through the pedicle into the vertebral body being treated. Different approaches have been used for the advancement of the cannula followed by the injection of the bone cement. The cannula is inserted between the lateral margin of the thoracic vertebra and rib head in parapedicular approach, while the unipedicular approach involves insertion between the middle and anterior thirds of the vertebral body[15]. After the uni or bipedicular access is obtained, the bone cement is injected. The bone cement PMMA mixed with some contrast agent (typically barium sulfate) is injected into the fractured vertebra. It takes about 20 min to set and achieves 90% strength within 24 h. The patient is expected to feel pain relief within 4 to 24 h. The entire process is guided with real-time fluoroscopic imaging. Kyphoplasty involves the transpedicular or extrapedicular insertion of a pair of balloons (or tamp) under fluoroscopic guidance into the VB, followed by inflation/deflation to create a cavity inside the cancellous bone. After the realignment of the endplates of the vertebra (if possible), balloons are retrieved and PMMA is injected into the cavity.

PV and PK clinical outcome:

PV and PK are the most routinely used minimally invasive procedures to treat osteoporotic or tumor-associated VCFs with the primary aim of relieving pain. There are several literature review articles that assess the efficacy and safety of these procedures in comparison to medical management alone in VCFs patients.

Prior to 2009, no prospective randomized controlled trials evaluated the effectiveness of cement augmentation (i.e., vertebroplasty, kyphoplasty) for osteoporotic VCFs. Since that time, many prospective RCTs have been published in the peer-reviewed literature .

The first two studies were published in the New England Journal of Medicine (NEJM) and were used by the AAOS in developing its guidelines for the treatment of osteoporotic VCFs[16, 17]. In their studies, Kallmes et al [16] and Buchbinder et al [17] compared vertebroplasty with sham procedures and found no beneficial effect of cement augmentation. Despite being level I studies, both had methodologic flaws. It is generally accepted that cement augmentation is most beneficial for acute fractures that do not respond to traditional nonsurgical care. These studies included subacute fractures that were up to 12 months old, and bone edema on MRI was not a consistent inclusion criteria. Furthermore, cement augmentation was compared only with sham procedures and not with traditional nonsurgical management. Therefore, the results of these trials were limited, and the best treatment option remained unclear. Since the publication of these two NEJM articles in 2009, there have been six separate prospective RCTs on cement augmentation for the treatment of osteoporotic VCFs [18-26]. Five of the studies have shown favorable results of cement augmentation compared with non-surgical care, [18, 20, 22-26] whereas one study demonstrated no beneficial effect compared with control subjects [19, 21]. In 2013, Anderson et al [8] performed a meta-analysis of vertebral augmentation compared with nonsurgical management of osteoporotic spinal fractures and included six of these prospective RCTs, including the studies by Kallmes et al [16] and Buchbinder et al [17]. The outcomes of interest were pain (i.e., as measured by visual analog scale [VAS]), spine-specific function, and HRQOL).The results of this meta-analysis showed cement augmentation to result in significantly greater pain relief, functional recovery, and improvement in HRQOL than did nonsurgical or sham treatment. The results were significant for early and for late follow-up end points (ie,6 to 12 months), favoring vertebroplasty (P, 0.001).

McGirt et al.[27] Published a systematic literature review covering a large number of articles published between 1980 and 2008. The studies were classified in different categories based on the level of evidence and grades of recommendation in support of using PV or PK according to the clinical guidelines of North America Spine Society (NASS) – (i) Level I studies with consistent findings (Good Evidence); (ii) Level II or III studies with consistent findings (Fair Evidence); (iii) Level IV or V with consistent findings (Poor Quality Evidence); and (iv) studies with inconsistent findings or lack of evidence (Insufficient Evidence)[28]. According to the level of evidence rated by NASS, among 74 published articles on PV until 2008, only 1 article classifies as Level I (randomized control trial) , 3 articles qualify for Level II (nonrandomized control trials) [29-31], while the remaining 70 classify as Level IV [32-39] .

McGirt also referred to 35 articles (1980–2008) reporting the status of patients receiving PK for the treatment of osteoporotic VCFs. Among these 35, there was no study that qualified for Level I ranking, and a

single Level II study was published in 2 separate manuscripts [40, 41]. In the first study, greater pain relief and faster return to daily activity was reported within 3–6 months of treatment in the PK cohort relative to optimum pain medication (OPM). There were fewer back pain-related doctor visits in the PK cohort. The second manuscript compared the outcomes of the patients treated with PK and OPM after 1 year, reporting greater reduction in pain at 12 months, improvement in physical functioning at 6 months, and reduction in back pain within 12-month related doctor visits, and fewer incidences of new adjacent VCFs in KP compared to the OPM cohort. The remaining 33 articles qualified as Level IV evidence, showing substantial, consistent, and rapid pain relief [42-45].

There are 3 outcomes in PV and PK interventions: (i) rapid pain relief, (ii) improved body functioning, and (iii) vertebral height gain or improved spinal alignment. Direct comparison in terms of efficacy of PV and PK is not possible as there is no randomized control trial. In a comparative systematic review, Taylor et al. [46] included 1 prospective study and 70 case series comparing the 2 procedures (PV and PK) for the treatment of VCFs due to osteoporosis or tumors. Similar findings of substantial reduction in pain were achieved for vertebroplasty at 5-year follow-up, and for kyphoplasty at 2-year follow-up. Physiological function was evaluated by the Oswestry Disability Score and Back Function Index. Kyphoplasty showed a substantial improvement in the patient's functional capacity. However, due to lack of a validated measurement of the patient's functional capacity, the outcomes are missing for vertebroplasty. Kyphoplasty also substantially improved the quality of life, but here again, due to different outcome measurements for vertebroplasty, the data cannot be compared. Vertebroplasty did show an improvement in quality of life. The single study comparing PV directly with PK found that level of pain relief measured by VAS was similar in both procedures [47]. However, the selection of application of procedures was notably biased, with more severe VCFs receiving kyphoplasty. Eighty-four percent of patients had substantial or complete pain relief with a short mean follow-up of 4.5 months [47]. Both procedures resulted in improved vertebral height gain and kyphotic deformity [40, 47].

Hulme et al. [48] published a systematic review comparing vertebroplasty and kyphoplasty, including 69 clinical studies. In this analysis, more than 80% of cases were osteoporotic VCF. The review examines the outcomes of 4456 vertebroplasty and 1624 kyphoplasty procedures. Pain relief was observed in both groups (vertebroplasty, 87%; kyphoplasty, 92%). In most of the studies included in this systematic review, the follow-up observation was of short duration (less than 1 year); however, the pain-relief was persistent. Physical function and disability score improved in both procedures, despite the fact that the data could not be pooled because different scales were used by the research groups in evaluating those scores. Similar vertebral height gain (or kyphotic angle restoration) was achieved by both procedures, with a mean kyphotic restoration angle of 6.6°. However, there was no vertebral height gain or correction in kyphotic deformity in 39% of vertebroplasty and 34% of kyphoplasty cases. Restoration of vertebral height depends on the age of the fracture, as suggested by a few authors [49, 50], although not validated globally [51]. Due to

the wide variation in measurement scales and lack of prospective data comparing the 2 approaches, it is not possible to make direct comparisons between vertebroplasty and kyphoplasty. Therefore, debate still exists regarding the superiority of one procedure over the other. Extent of pain relief and vertebral height gain were found to be similar with both procedures[52]. However, the controversy lies in the vertebral height gain, cost efficiency, safety, and efficacy of these 2 procedures.

The optimal timing of cement augmentation remains controversial, and many patients who sustain a VCF improve with symptomatic/nonsurgical care. Nevertheless, the results of the meta-analysis show greater pain relief, functional recovery, and HRQOL with cement augmentation compared with control subjects. Based on the current literature, cement augmentation should be considered in patients who sustain an acute VCF confirmed by the presence of edema on MRI—and who are incapacitated by pain and unable to mobilize, or in patients who do not adequately improve within a reasonable period (i.e., 3 to 6 weeks) of nonsurgical management; however, the ideal time frame for a trial of nonsurgical care is still unclear.

Cement augmentation has been used to treat symptomatic VCFs for many years. Kyphoplasty provides the added advantage of vertebral body expansion and correction of kyphosis before the injection of cement. The radiographic advantages of kyphoplasty compared with vertebroplasty have been documented in the literature; however, the impact on clinical outcome is controversial.

Han et al [53] published a systematic review of the literature comparing vertebroplasty and kyphoplasty. Eight studies (i.e., one prospective RCT, three clinical controlled trials, three prospective cohorts, and one retrospective cohort) involving 848 patients were included in their analysis. These authors concluded that vertebroplasty is more effective in short-term (i.e., no more than 7 days) pain relief, whereas kyphoplasty had a superior capability for intermediate-term (i.e., approximately 3 months) functional improvement. There was no difference between the two in long-term pain relief or functional improvement. Omidi-Kashani et al[54] compared percutaneous kyphoplasty with vertebroplasty in single-level osteoporotic compression fractures. They found significant improvement from baseline in both VAS and the Medical Outcomes Study 36-Item Short Form in both treatment groups. Kyphoplasty has been shown to improve the kyphotic angulation at the fractured vertebra [25] however, there appears to be no difference in pain and functional outcomes between vertebroplasty and kyphoplasty. Conclusions from these studies are limited because the results are heterogeneous and with a high likelihood of bias because most of the studies were sponsored by industry.

Complications:

There are some perioperative and postoperative adverse events associated with both PV and PK, such as symptomatic cement leakage, cement embolism, pulmonary embolism, hematoma, neurodecline, spinal cord compression, radiculopathy, infection, and adjacent vertebral fracture[37, 48, 55, 56]. Hulme et al

reported the rates of neurological complications with PV and PK were 0.6% and 0.03%, respectively [48]. CT studies show that cement extravasation occurs in most patients (i.e., 18% to 88%) but is of minimal significance. [57] The most common site of cement leakage is into the end plate or disk (45%), followed by paravertebral (35%), epidural (20%), and prevertebral (18%). CT detects substantially more leaks than plain radiography. [57] Cement leak-age has been correlated with lower viscosity, more severe fracture, and higher injected volumes. [58]. Neurologic complications occur in .1% of patients, but when complications are present, the patient may require decompression and reconstruction. Cement augmentation has also been associated with permanent neurologic deficits. Leakage into the disk space may create stress risers in the adjacent end plate and lead to subsequent fracture.

As a result of bone cement leakage into the venous channel, lethal conditions such as pulmonary embolisms occur, with rates ranging from 0.6% (for PV) to 0.01% (for PK)[48]. The extent of cement leakage depends on the cause of the VCFs. The incidence of cement leakage was higher in the treatment of osteoporotic VCFs than in tumor-associated VCFs[59]. Phillips et al reported significantly less contrast extravasation-related complications in PK when compared to PV [OR (95% CI): .04(.00-.68) P=0.03] [120]. The periprocedural complications involve fractures for transverse process, pedicle, sternum, ribs,[27, 49, 60-63], respiratory distress due to anesthetic complications [4, 64, 65], and infections [63, 66]. Other complications include epidural hematoma, partial motor loss [67], and digestive tract bleeding[50]. Walker et al. reported osteomyelitis a rare complication, which requires corpectomy [68].

The increased stiffness from vertebroplasty results in increased loads on adjacent segments and may make the occurrence of new fractures more likely. However, in a meta-analysis of RCTs comparing vertebroplasty with nonsurgical care, no increased risk of secondary fracture was present [8]. Approximately 20% of patients in both groups experienced the development of new fractures between 6 and 12 months after the procedure. Technical problems such as extravasation into the disk space may increase the likelihood of a new fracture. One limitation of this meta-analysis was that it included patients who had as many as three VCFs; the risk of new fractures after cement augmentation may be increased in patients with multiple fractures, with a kyphotic deformity, or with widespread metastatic disease. In addition, whereas some patients may have adjacent level fractures, cement failure can develop in some patients because of refracture at the index level around the cement. Another attempt at cement augmentation may salvage the failure; however, this procedure has been poorly documented.

Cost Effectiveness of Cement Augmentation:

The current literature suggests that stabilizing a painful osteoporotic VCF with cement augmentation provides significant pain relief, improves function, and increases HRQOL. The treatment effect may decrease with time because patients undergoing nonsurgical management also often improve as the fracture heals.

Therefore, the cost effectiveness of cement augmentation includes a time variable and essentially calls into question what society is willing to pay for in terms of more rapid pain relief and increased quality of life. Thus far, results in the literature are controversial. In a prospective RCT, Fritzell et al [69]KYHO found that kyphoplasty was not cost effective compared with standard medical treatment in patients treated for an acute/subacute VCF, with a cost/quality-adjusted life-year (QALY) gained for kyphoplasty of \$134,043 based on 2-year follow-up data. In contrast, kyphoplasty was found to be cost effective for treating patients hospitalized with VCFs in the United Kingdom. [70] In the absence of any conclusive data that show kyphoplasty to be superior to vertebroplasty in improving pain and/or HRQOL measures, it may be difficult to justify the increased costs associated with the kyphoplasty procedure.

CONCLUSIONS

Osteoporotic spinal fractures are associated with significant morbidity and an increased risk of mortality. These fractures often cause a notable amount of pain and therefore are associated with functional disability and a decreased quality of life, as measured by HRQOL scores. Several studies have shown a significant increase in risk of mortality in patients who sustain osteoporotic spinal fractures. The treatment of osteoporotic spinal fracture is predominately non-surgical, with exceptions in patients who have a neurologic injury and/or disabling pain. To date, eight prospective randomized controlled trials have evaluated the efficacy of cement augmentation for the treatment of osteoporotic VCFs. The meta-analysis performed by Anderson et al [8] showed greater pain relief, functional recovery, and HRQOL with cement augmentation compared with control subjects. Kyphoplasty appears to show favorable radiographic results compared with vertebroplasty but shows no differences in clinical results and is considerably more costly. Based on the current literature, cement augmentation may be considered in patients who sustain an acute VCF (i.e., confirmed by the presence of edema on MRI) and who do not adequately improve after a reasonable course (i.e., 3 to 6 weeks) of nonsurgical management

Percutaneous vertebroplasty and percutaneous kyphoplasty both are effective in vertebral augmentation and pain-relief in patients with osteoporotic VCFs. Both procedures have been proven to be superior to oral pain management. However, due to lack randomized trials, there are no data available for direct comparison between these 2 procedures. On the basis of systematic reviews of available literature, indirect comparisons have been found that showed very little difference in terms of clinical outcomes of these 2 procedures. Both procedures give immediate pain relief and improvement in physical functioning, although the effect is not long-term. The overall rate of complications associated with these 2 procedures is low, but the rate of cement extravasation is higher in PV. Controversy exists about symptomatic and asymptomatic cement leakage, as most of the cement leakage in PV is asymptomatic. Improved vertebral height restoration with PK is also controversial, because initial height gain is higher in kyphoplasty but this effect is lost subsequently during balloon deflation and repetitive loading. Clinical studies consistent with these findings

found little difference in vertebral height gain between PV and PK. Postoperative adjacent level vertebral fracture is another subject of debate. Recently-developed radiofrequency kyphoplasty showed promising results in terms of height restoration and other procedure-associated complications like trabecular destruction, which frequently occurs in balloon kyphoplasty. To establish the relative strengths and weaknesses of all these procedures, well-designed randomized clinical trials are required. Further research should concentrate on the development of new material and method that can overcome the drawbacks of these existing procedures, and come up with a new promising alternative technique with long-term efficacy and improved safety.

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