Surgical Therapy: Vertebro-Cifoplastic: – Pros and Cons

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18.1 Introduction

The prevalence of osteoporosis increases with increasing age of the population. Osteoporosis can lead to osteoporotic vertebral compression fractures (VCFs), being the most serious complaint for elderly people worldwide, followed by hip, wrist, and ankle fractures [1]. Osteoporotic VCFs are known as low-energy fractures or insufficiency fractures because the fragility of the bone is the main cause to injury with minimal or no trauma. In fact, we can define an osteoporotic fracture if it occurs in a person as a result of little or no trauma, the equivalent of a fall from standing position or lower [2]. In the United States, there are approximately 700,000 and in Europe 450,000 cases of osteoporotic VCFs every year although only one-third are diagnosed [3]. Incidence is doubled in menopausal women, and about 8% of women over 50 years of age and 27% of women over 80 years have VCFs [4]. The vertebra is compressed resulting in a reduction of its height and an abnormal increase of the curvature of the spine with kyphosis. Vertebral fractures may be symptomatic or asymptomatic. Symptomatic, or clinical, vertebral fractures cause either sufficient pain for the patient to bring them to the attention of a health professional or a measurable loss of height. Vertebral body height may be measured at posterior, middle, and anterior parts of the vertebra. Genant's semiquantitative method is the most accepted technique to classify the changes in vertebral body in terms of reductions in overall height and also indicates fracture severity. Then, vertebral bodies can be classed as normal (grade 0), mildly deformed (grade 1,

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reduction between 20 and 25% in anterior, middle, and/or posterior height and a reduction of area of 10–20%), moderately deformed (grade 2, reduction between 25 and 40% in anterior, middle, and/or posterior height and a reduction of area of 20–40%), and severely deformed (≥40% reduction in any height and area) [5]. Another classification for vertebral fracture is the Magerl one [6] based on purely morphological criteria; it is the most widely used system. It distinguishes three types of fracture (A = pure compression, B = distraction, C = translation or rotation), three groups and three subgroups, using the AO codes. Its interest lies in its good predictive value, with vertebral instability increasing from type A to type C. The most important consequence of VCFs is the acute pain, which may be persistent. The pain is exacerbated by movement and reduced by rest and may therefore limit mobility. Also, the risk of pain and disability increases progressively with the number and severity of vertebral deformities. In some patients, the acute pain is followed by chronic pain with progressive loss of height, kyphosis, and impairment of daily activities. Many studies have shown that the quality of life, assessed with QUALEFFO tests, is worse in the presence of a VCF, and these are accompanied by sleep disorders, psychiatric problems, impaired mobility, pulmonary complications, and increased mortality rates [7–9]. An important consequence after the first vertebral fracture is certainly the risk of developing new vertebral fractures that increases five to ten times [10]. Vertebral fractures can be linked to the risk of having fragility refractures also to other sites like the femur, wrist, and humerus [11, 12].VCFs commonly occur in the mid-thoracic, low thoracic, and high lumbar areas and mostly at the thoracolumbar junction, especially T12 and L1 [13]. Historically, surgical treatment is indicated for patients with VCFs and neurological deficits or spinal instability. Since the surgery entails for these elderly patients with VCFs and comorbidities greater health risk, conservative treatment that consists a short period of bed rest to avoid complications caused by immobilization and external brace is recommended. Pain medication with oral analgesic and narcotics which can be effective for fracture pain are also indicated, while nonsteroidal anti-inflammatory drugs (NSAIDs) may relieve pain associated with inflammation and muscle spasm [14]. Anti-osteoporosis medications with vitamin D should be prescribed to reduce the risk of further vertebral fractures, also reducing risk of fall. Conservatively treated VCFs are cured with partial relief of pain and quality of life within 2–12 weeks [15]. However, conservative treatment with long periods of inactivity can lead these elderly patients to pneumonia, bedsores, venous thromboembolism, new VCFs, and sometimes death. Furthermore, narcotic analgesics may lead to debilitating side effects, in particular cognitive impairment, nausea, and constipation, while NSAIDs are associated with gastrointestinal side effects such as nausea, gastritis, and ulcers. Unfortunately, these side effects tend to be more pronounced in frail older people.

Open surgery with internal fixation may be performed in patients whose pain does not resolve with conservative management, but the high morbidity and the high costs of surgical treatment related to VCFs make it a duty to find alternative, more effective, and less invasive treatments than open surgery. During the past 30 years, two kinds of minimally invasive spine surgical treatment have been increasingly used. Currently, the two main minimally invasive techniques are percutaneous

vertebroplasty (PVP) and kyphoplasty (PKP) [16]. Both procedures are based on the injection of a bone cement of polymethyl methacrylate (PMMA) into the fractured vertebra for the mechanical stabilization of VCFs and for pain relief. Percutaneous vertebroplasty is an injection of PMMA bone cement into the vertebral body via a needle using a transpedicular or extrapedicular approach, with monolateral or bilateral approach. It may be performed under general anesthesia, although more commonly the procedure is performed under local anesthesia [17]. Deramon and Galibert introduced for the first time PVP for the treatment of painful hemangioma in 1984 [18]: the result was so gratifying in pain relief that many other surgeons use and extended the indications for PVP including osteoporotic compression fractures, traumatic compression fractures, and painful vertebral metastases [17]. Lieberman et al. in 2001 described the initial outcome and efficacy of a new minimally invasive spine procedure in the treatment of painful VCFs, kyphoplasty [19], biomechanically developed by Reiley and Belkoff [20]. The basic ideas behind PKP were to treat kyphosis deformity and restore vertebral size: PKP is a technique that involves the introduction of inflatable bone tamps into the vertebral body. Once inflated, the bone tamps restore the vertebral body back toward its original height while creating a cavity that can be filled with bone cement.

The inflation of the device via a radiopaque liquid restores the vertebral size and helps to correct the kyphotic deformity. The balloon is deflated and replaced by a cement made of PMMA. PVP and PKP are clearly advantageous compared to conservative treatment or open surgery in terms of pain and function. In older patients, percutaneous vertebral augmentation may promote early mobilization and reduce analgesic intake [21].

The analgesic effect of bone cement injection into the vertebra may result from the fixing of microfractures and the decrease of the mechanical stresses associated with the body weight and mobility. Furthermore, nerve endings are destroyed by the cytotoxic and exothermic action during the polymerization of the bone cement, reducing the pain. However, the benefits and shortcomings of these two techniques are still debated such as height restoration and bone cement leakage [22]. The maximum number of vertebrae augmentable per session should be three, although extensive augmentation to more than three vertebral levels per session has been shown as feasible [23].

Conventional radiographs are usually the first technique used to study patients with suspected vertebral fracture in osteoporotic patients. A 20% vertebral body height loss or 4 mm of vertebral height reduction constitutes the diagnosis of a vertebral compression fracture. But in many cases of osteoporotic vertebral fractures, morphologic changes may require time for their development. Therefore, the absence of a fracture on X-ray in an osteoporotic patient does not rule it out, and when symptoms persist, a magnetic resonance imaging (MRI) should be performed. In order to identify the VCFs with or without vertebral deformities and degree of edema, assess its age, define its anatomy, assess the posterior wall of the vertebral body, and exclude other causes of back pain, MRI is a requisite to screen all patients who are considered for planning medical, PVP, PKP, or open surgical treatment [24]. The presence of a pattern of bone marrow edema is associated with a good

clinical short-term success relieving pain [25]. However, CT scanning or bone scintigraphy may be used instead when MRI is unsafe (e.g., in patients with pacemakers). CT equipment is also required if there are any doubts regarding the integrity of the posterior vertebral wall [26].

18.2 Technical Issues

PVP is performed under radiological guidance using fluoroscopy. It is usually performed using local anesthesia of the skin, subcutaneous tissue, and the periosteum of the vertebral body into which the needle is to be introduced; sometimes conscious sedation is an addiction. The patient is clearly positioned prone. A small skin incision is made and a disposable bone biopsy needle or trocar needle is placed centrally in the vertebral body using an image-guided safe access route. This may be done bilaterally or monolaterally through the pedicle, obliquely across one pedicle, or laterally oblique through the base of the pedicle. Under constant screening with X-ray image intensifier, it is advanced through the pedicle into the vertebral body; an orthopedic hammer can be useful in case of sclerotic cortical bone. The cement is then injected very slowly, again under constant fluoroscopic screening.

In unilateral approach, rotating the trocar tip, the cement can be spread throughout the vertebral body. In bilateral approach to achieve optimal vertebral filling, two trocars may be used, one on either side of the midline. The procedure may last from 15 min to 1 h, depending on the number of vertebrae being treated and the experience of the surgeon. Computed tomography (CT) scanning could be indicated at the end of the procedure to assess the distribution of cement and identify any complications [27].

PKP is a variant of PVP in which one or two balloon-like devices are inserted bilaterally into the vertebral body, through a transpedicular approach. A small balloon catheter surrounded by a metal stent is inserted into the vertebral body using a minimally invasive percutaneous approach under radiographic guidance and either local or general anesthetic. The balloon catheter is then inflated with liquid, under pressure, to create a cavity in which the stent is expanded. Balloons are slowly inflated until they reach their highest achievable volume, in order to restore vertebral body height. The balloons are then deflated and removed, leaving a cavity which is filled with PMMA bone cement; because of the existence of the cavity, the cement may be injected at a lower pressure than that used for PVP. The injected cement hardens within 1 h, and the patient may then be mobilized [17].

PVP and PKP are traditionally performed using PMMA to which a radiopaque substance such as barium, tantalum, or tungsten sulfate has been added to facilitate visualization during the procedure when polymerization of methyl methacrylate monomers to PMMA polymers occurs. It is prepared by mixing a liquid component containing the monomer, accelerator, and inhibitor with a powder containing the polymer, radio-opacifier, and initiator. It is cheap and easy to manipulate and gives the appropriate stiffness and strength to the vertebral body. However, there are no osteoinductive or osteoconductive properties and, therefore, no integration with

host bone over time. Its stiffness may promote mechanical overload to adjacent vertebral bodies [28]. PMMA appears to have analgesic properties quite apart from those caused by the effect of the stability provided by the cement within the weakened vertebrae. The reason for such analgesic properties remains unclear, but one possibility is that it destroys or damages local nerve endings as a result of both the toxic effects of the free monomers of PMMA and the heat caused by the cement polymerization [29].

18.3 Criteria for Treatment

The National Institute for Health and Care Excellence guidance indicates that PVP and PKP should be limited to patients whose pain is refractory to more conservative treatment for PKP; there is an additional requirement that they should have continued vertebral collapse and severe pain [30, 31]. Recent guidance from the Cardiovascular and Interventional Radiology Society of Europe (CIRSE) states that PVP is indicated in patients with "painful osteoporotic VCFs refractory to medical treatment." It defines failure of medical treatment as "minimal or no pain relief with the administration of physician-prescribed analgesics for 3 weeks or achievement of adequate pain relief with only narcotic dosages that induce excessive intolerable sedation, confusion, or constipation." In case of painful patients at high risk of complications resulting from immobility (e.g., thrombophlebitis, DVT, pneumonia, or pressure ulcer), CIRSE guidelines further note that PVP may be considered at the beginning.

Contraindications
The CIRSE guidelines list the following absolute contraindications to PVP:

- Asymptomatic vertebral body compression fracture
- Patient improving on medical treatment
- Osteomyelitis, discitis, or active systemic infection
- Uncorrectable coagulopathy
- Allergy to bone cement or opacification agents
- Prophylaxis in osteoporotic patients

Relative contraindications in osteoporotic patients include:

- Radicular pain
- Tumor extension into the vertebral canal or cord compression
- Fracture of the posterior column and increased risk of cement leak
- Vertebral collapse >70% of body height (needle placement might be difficult)
- Spinal canal stenosis and asymptomatic retropulsion of a fracture fragment causing significant spinal canal compromise
- Patients with more than five metastases or diffuse metastases
- Lack of surgical backup and monitoring facilities

These contraindications appear to be equally applicable to PKP.

18.4 Clinical Evidences of PVP and PKP

PVP and PKP are therapeutic alternatives for patients in whom conservative treatment failed. They are minimally invasive procedures and seem to determine a rapid and sustained pain relief with a better quality of life. Although many studies have shown good clinical outcomes and improved quality of life after PVP and PKP, there is an ongoing debate on which of these two procedures can provide the most important efficacy and safety.

Analgesic effect of these techniques can be related to some factors, such as the thermal effect of the cement that produces the ablation of C-nociceptive fibers, the mechanical stabilization of the fracture, and the height restoration of the vertebral body [32]. Compared with medical treatments, short-term pain relief and long-term beneficial effects after PVP seem to be significantly superior [33]. Recent studies demonstrated that most patients who had favorable clinical results with conservative treatment for 3 weeks after the fracture also had successful clinical results at 1 year. If the patient failed conservative treatment, percutaneous cement augmentation also showed excellent results at 1 year after the trauma. However, the long conservative treatment period of 3 weeks has been criticized by other authors [34].

A follow-up survey indicated that patients who underwent percutaneous vertebroplasty were significantly more satisfied with given treatment than patients who underwent conservative treatment. In addition, lower rate of complications was observed in percutaneous vertebroplasty group [35].

Postoperative pain relief in osteoporotic VCFs has been shown in the literature using PVP and PKP, which was measured by the VAS pain scale. However, many studies showed that the follow-up point at which the difference becomes really insignificant varies after 3, 6, or 12 months [36]. Improvement in VAS score was not statistically significant between PVP and PKP groups. The potential reason for the similar pain scores is that clinical heterogeneity was induced by a double blind, the duration of illness, types of fractures, gender differences, and insufficient sample size bias [37]. Moreover, the natural history for spontaneous pain reduction is 3 months [38].

In this context, the results from a recent meta-analysis are focused on the timing in case of significant VAS reduction and showed that PKP has significantly lower VAS scores in the short-term follow-up, but at long-term follow-up, results were comparable [39].

Compared with medical treatments, two prospective controlled studies evaluated and compared the efficacy and safety of PKP and found better long-term pain relief and superior functional outcome up to 3 years [40, 41]. It was shown that both PKP and PVP can restore kyphosis. According to this meta-analysis, the angle of postoperative kyphosis was significantly improved in the short- and long-term follow-up in the PKP group. Patients who underwent PKP had a higher

kyphosis angle improvement if compared with patients who underwent PVP, and there was a slight loss of kyphosis angle correction between the short- and long-term follow-up. As reported in previous studies, the improvement in kyphosis angle with PKP and PVP has been attributed in part to the lying position that patients assume during the operation and in part to the failure of the two end plates of the fractured vertebra. PKP corrects the kyphotic deformity through the expansion of a balloon, and this seems to be more beneficial to restore the vertebral size and correct the kyphotic deformity compared to PVP. A further advantage of PKP is the creation by the inflatable balloon of a cavity, which allows to inject larger quantities of cement compared to PVP [42]. Mechanical stabilization of the vertebral body relies on quantity and localization of the injected cement. The filling of 16–30% of the volume could recover the vertebral stiffness partially at the pre-fracture state, and this would be enough to obtain clinical healing [43]. Cadaveric studies have shown that kyphoplasty had greater recovery of vertebral height than vertebroplasty [44]. However, clinical studies are contradictory. Some authors found greater height restoration with kyphoplasty, but others did not find differences between both techniques [45]. Some studies found no better pain resolution with height restoration and do not consider this factor mandatory in order to achieve pain control [46].

Meta-analysis of published papers shows fair to good evidence that in patients with osteoporotic VCF outcomes on physical disability, general health and pain relief are better with PVP and PKP than with medical management within the first 3–6 months after intervention [47]. There is fair evidence that by the first or second year after intervention, PVP provides a similar degree of pain control and physical function as that obtained with optimal medical management. PKP seems to be superior to PVP according to short-term pain relief, kyphosis angle correction, and cement leakage.

A recently presented preliminary 1-year results of the multicenter randomized controlled Fracture Reduction Evaluation (FREE) study confirmed in the kyphoplasty group a significant improvement of the quality of life and VAS scale pain scores and function after 1 month controlled against nonsurgical treatment. These treatment effects diminished dramatically until the 12-month follow-up but were still significantly better than nonsurgical treatment for quality of life [40].

Controversy remains regarding whether a unilateral or a bilateral approach is superior, and there are no large studies comparing these two approaches. A recent meta-analysis tried to find if there is an evidence to suggest a benefit in clinical outcome of a unilateral kyphoplasty or bilateral kyphoplasties, but no clinically important differences were found between them. Only considering less operation time and less cost, a unilateral percutaneous kyphoplasty could be considered an advantageous method. [48]

Women with preexisting VCFs have a four times increased risk of subsequent vertebral fracture, but these fractures seem to be not different between the PKP and PVP groups [49]. There is insufficient evidence whether PKP results in greater pain relief 1 and 2 years after intervention [50].

18.5 Complications of PVP and PKP

International literature is unanimous about the low rate of complications associated with PVP and PKP when treating osteoporotic VCFs [43]. The cement leakage is one of the most common complications associated with PKP and PVP. Leakage occurs when the cement is not wholly contained by the fractured vertebra but escapes through either the fracture or the track created by the needle. Systematic reviews provided that little cement leakage is found after PVP and PKP by the standard X-ray imaging, whereas high rates are observed with computed tomography [51]. There are many routes by which cement may leak from a vertebra: paravertebral leakage, venous leakage, or leakage into the spinal canal and intervertebral foramen. Injury of the surrounding soft tissues is mainly due to the high temperature of polymerization of PMMA. The most sensitive structures are neural tissues, spinal cord, and nerve roots. Fortunately, most of the extravasations are to the disc or paravertebral tissues, hence asymptomatic. Transient radicular symptoms have been described in up to 3–4% of the patients, and only isolated cases of paraplegia after these procedures have been reported, most of them due to failure of technical issues. The monomers that do not contribute to the polymerization have systemic cardiopulmonary effects. Pulmonary embolism can be due not only to the cement but also to the fat from the bone marrow extruded into the venous system by the high-pressure cement injection or by inflating the balloons [52]. Although all of the included studies reported the incidence of cement leakage, no cases of spinal stenosis and pulmonary embolism due to cement leakage were reported. The Food and Drug Administration (FDA) states that PMMA is contraindicated in the presence of active or incompletely treated infection at the site where the cement is to be applied. It also notes that hypotensive reactions have been noted between 10 and 165 s after its application; as these have lasted from 30 s to over 5 min, and some have progressed to cardiac arrest, the FDA recommends that patients should be monitored carefully for any changes in blood pressure during and immediately following the application of the cement. Other reported adverse events include pyrexia due to allergy to the cement. In addition, the FDA notes that the heat released while the cement is hardening in situ may damage the bone or other tissues surrounding the implant [53].

In a systematic review of the literatures, the risk of experiencing new VCFs increased after PVP and PKP. Retrospective and prospective studies found an incidence of recompression of 12.5–36.8% after PVP and PKP [54, 55]. From the standpoint of vertebrae, adjacent recompression occurred more frequently than distant levels, and it demonstrated a remarkable propensity of refractures within three levels above or below preexisting fractures [56]. The exact mechanism for refracture is still unclear. Several authors indicate that the cemented vertebra can change the biomechanics of the spine with increased stresses and strains and therefore may increase the incidence of new adjacent VCFs. The greater height of the collapsed vertebra increases the tension of the soft tissues around it and can lead to an increase of the load on other vertebrae, especially adjacent [57]. Other authors also suggest that a wedge-shaped fracture increases the flexion bending

moment due to the upper body weight, and thus a higher muscle force in the erector spinae is required to balance the spine, which results in a higher spinal load and a higher intradiscal pressure [58]. The erector spinae are a long muscle, and thus its force affects intradiscal pressure not only at adjacent levels but also the whole region.

Conclusion

PVP and PKP are two minimally invasive spine augmentation procedures which can increase bone strength as well as reduce the pain produced by VCFs, and both techniques depend on PMMA cement injection into the fractured vertebra for mechanical fixation. The advantage of PVP and PKP in comparison to conservative treatment including bed rest, painkillers, and bracing or open surgery has been well established in terms of pain and functional outcome. PVP and PKP produce immediate pain relief, and when compared with conservative management at least at 1 year, PVP and PKP are superior on clinical improvement with reduction in the use of analgesic drugs. Furthermore, PKP can restore the vertebral height in VCFs. Anyhow some studies report that there are no statistically significant differences in the vertebral height restoration and kyphosis angle correction of between PKP and PVP.

Cement leakage and new VCFs at the adjacent level are the most common complications. Cement leakage is more frequent in PVP [59]. Leakage into the disc space is more frequent in cases of cortical defect of the end plate or vertebral cleft than intrasomatic collapse, but there is no statistically significant correlation between intradiscal leakage and fracture severity, kyphosis angle, treated level, age, and sex of the patient [60]. High-viscosity PMMA significantly reduces the risk of leakage and related complications, and lower amount of cement is required [61].

According to the literature, the "domino" effect is present in both PVP and PKP but with different results probably depending on the heterogeneous characteristics of the patients studied. Hierholzer et al. reported 16% of new symptomatic VCFs after PVP but without considering new asymptomatic VCFs [62]. Klazen et al. reported 19.7% of new VCFs following PVP, but no statistically significant difference on the incidence of subsequent vertebral fractures between vertebroplasty and conservative treatment was found [63]. Different studies reported a higher incidence (15–25%) of consequent vertebral fracture after PKP compared with PVP; consequent fractures occur more frequently at the adjacent level to the treated vertebra [64–66].

From a biomechanical point of view, 2 ml of bone cement is sufficient to reinstate the bone strength of the vertebral body [67], but it has been calculated that the minimum dose of cement required to restore the resistance is about 16% of the vertebral volume, while the quantity necessary to restore vertebral hardness is 30%; then, as the vertebral bodies have different volumes depending on the segment concerned, it must take into account the level to be treated. Injection of large amounts of cement in order to obtain a better result is not needed;

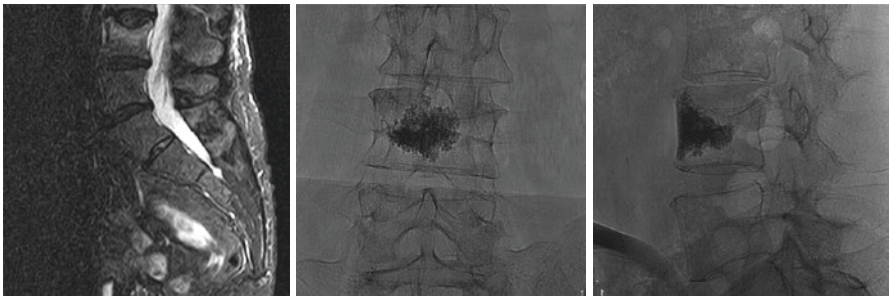
according to Kaufmann et al., there was no significant association between the volume of the cement injected and the clinical outcomes of postprocedure pain and medication use [68]. PMMA can cause adverse reactions during the polymerization (exothermic reaction) and have toxic effects. Within the vertebral body, the PMMA becomes a stranger inert body with disappearance of metabolic bone turnover, and for this reason new biocompatible, biodegradable, bioactive, and osteoconductive cements are the subject of numerous biomechanical and clinical investigations [69–73].

The ideal cement should be absorbable, nontoxic, with low polymerization temperature, biomechanically similar to the bone, and bioactive. The appropriate treatment of osteoporotic vertebral fractures requires understanding the effect of the disease on the material and structural properties of the bone tissue and the fracture healing process [74].

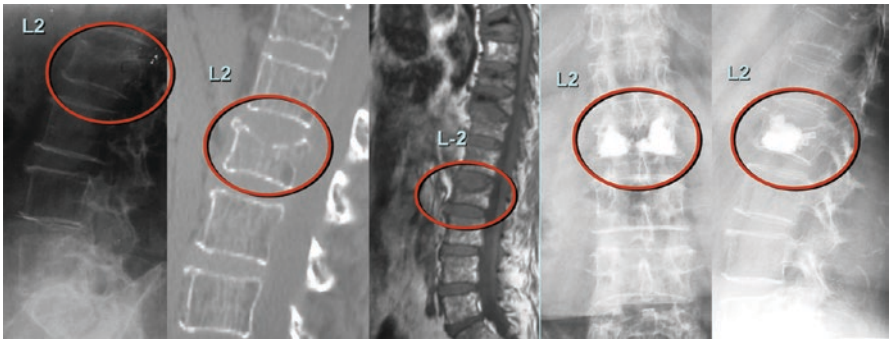
The careful reviewing of valid scientific publications shows that both vertebro- and kyphoplasty are effective and safe as minimally invasive procedures in the treatment of symptomatic vertebral collapse, but before using such procedures, it is important to keep in mind that the percutaneous interventional cementation methods do not treat the underlying metabolic bone fragility condition. They should be performed only after at least 3 weeks of unuseful conservative treatment, and they have better results when applied to antiosteoporotic therapy and physiotherapy. PVP and PKP are not free from complications and should be performed in multi-specialist centers with the presence of a multidisciplinary team (fracture unit), requiring an adequate informed consent of the patient as there are no absolute international guidelines based on evidence criteria.

Toolbox for Guidance

- Vertebro- and kyphoplasty are effective and safe as minimally invasive procedures in the treatment of symptomatic vertebral fractures, but they do not deal with the poor bone quality condition affecting osteoporotic patients (*grade A recommendation*).
- Vertebroplasty and kyphoplasty have better long-term pain relief and superior functional outcome up to 3 years if compared to conservative treatment (bed rest, painkillers, and bracing), and they should be performed only after at least 3 weeks of unuseful conservative treatment (*grade A and B recommendation*).
- The most frequent complications after vertebroplasty and kyphoplasty are cement leakage and new vertebral fractures at the adjacent level (*grade A recommendation*).
- These treatments should be always integrated with antiosteoporotic therapy and physical exercise if it is possible (*grade A and B recommendation*).



Case 1: L4 bone cement vertebroplasty for VCF in a 49-year-old glucocorticoid-induced osteoporotic woman



Case 2: L2 kyphoplasty (Vessel-X®) for VCF in a 65-year-old woman with multiple myeloma

References

1. Silverman SL. The clinical consequences of vertebral compression fracture. Bone. 1992;13(Suppl 2):S27–31.
2. Consensus development conference: diagnosis, prophylaxis, and treatment of osteoporosis. Am J Med. 1993;94:646–50.
3. Dennison E, Cooper C. Epidemiology of osteoporotic fractures. Horm Res. 2000;54(Suppl 1):58–63.
4. Bonnick SL. Osteoporosis in men and women. Clin Cornerstone. 2006;8:28–39.
5. Genant HK, Wu CY, van Kuijk C, Nevitt MC. Vertebral fracture assessment using a semiquantitative technique. J Bone Miner Res. 1993;8:1137–48.
6. Magerl F, Aebi M, Gertzbein SD, Harms J, Nazarian S. A comprehensive classifi-cation of thoracic and lumbar injuries. Eur Spine J. 1994;3(4):184–201.
7. Miyakoshi N, Itoi E, Kobayashi M, Kodama H. Impact of postural deformities and spinal mobility on quality of life in postmenopausal osteoporosis. Osteoporos Int. 2003;14(12):1007–12.
8. David C, Confavreux CB, Mehsen N, Paccou J, Leboime A, Legrand E. Severity of osteoporosis: what is the impact of co-morbidities? Joint Bone Spine. 2010;77(Suppl 2):S103–6.
9. Lombardi I Jr, Oliveira LM, Mayer AF, Jardim JR, Natour J. Evaluation of pulmonary function and quality of life in women with osteoporosis. Osteoporos Int. 2005;16(10):1247–53.

10. Lindsay R, Silverman SL, Cooper C, Hanley DA, Barton I, Broy SB, Licata A, Benhamou L, Geusens P, Flowers K, Stracke H, Seeman E. Risk of new vertebral fracture in the year following a fracture. JAMA. 2001;285:320–3.
11. Gallacher SJ, Gallagher AP, McQuillian C, Mitchell PJ, Dixon T. The prevalence of vertebral fracture amongst patients presenting with non-vertebral fractures. Osteoporos Int. 2007;18(2):185–92.
12. Ledlie JT, Renfro M. Balloon kyphoplasty: one-year outcomes in vertebral body height restoration, chronic pain, and activity levels. J Neurosurg. 2003;98:36–42.
13. Hansen L, Petersen KD, Eriksen SA, Langdahl BL, Eiken PA, Brixen K, Abrahamsen B, Jensen JE, Harsløf T, Vestergaard P. Subsequent fracture rates in a nationwide population-based cohort study with a 10-year perspective. Osteoporos Int. 2015;26(2):513–9.
14. Prather H, Hunt D, Watson JO, Gilula LA. Conservative care for patients with osteoporotic vertebral compression fractures. Phys Med Rehabil Clin North Am. 2007;18:577–91.
15. Brown CJ, Friedkin RJ, Inouye SK. Prevalence and outcomes of low mobility in hospitalized older patients. J Am Geriatr Soc. 2004;52:1263–70.
16. Garfin SR, Yuan HA, Reiley MA. New technologies in spine: kyphoplasty and vertebroplasty for the treatment of painful osteoporotic compression fractures. Spine. 2001;26:1511–5.
17. Hargunani R, Le Corroller T, Khashoggi K, Murphy KJ, Munk PL. Percutaneous vertebral augmentation: the status of vertebroplasty and current controversies. Semin Musculoskelet Radiol. 2011;15:117–24.
18. Galibert P, Deramond H, Rosat P, Le Gars D. Preliminary note on the treatment of vertebral angioma by percutaneous acrylic vertebroplasty. Neurochirurgie. 1987;33:166–8.
19. Lieberman IH, Dudeney S, Reinhardt MK, Bell G. Initial outcome and efficacy of "kyphoplasty" in the treatment of painful osteoporotic vertebral compression fractures. Spine (Phila Pa 1976). 2001;26(14):1631–8.
20. Belkoff SM, Mathis JM, Fenton DC, Scribner RM, Reiley ME, Talmadge K. An ex vivo biomechanical evaluation of an inflatable bone tamp used in the treatment of compression fracture. Spine (Phila Pa 1976). 2001;26(2):151–6.
21. Weninger P, Schultz A, Hertz H. Conservative management of thoracolumbar and lumbar spine compression and burst fractures: functional and radiographic outcomes in 136 cases treated by closed reduction and casting. Arch Orthop Trauma Surg. 2009;129:207–19.
22. Chandra RV, Yoo AJ, Hirsch JA. Vertebral augmentation: update on safety, efficacy, cost effectiveness and increased survival? Pain Phys. 2013;16:309–20.
23. Mailli L, Filippiadis DK, Brountzos EN, Alexopoulou E, Kelekis N, Kelekis A. Clinical outcome and safety of multilevel: clinical experience and results. Cardiovasc Intervent Radiol. 2013;36:183–91.
24. Cuénod CA, Laredo JD, Chevret S, Hamze B, Naouri JF, Chapaux X, Bondeville JM, Tubiana JM. Acute vertebral collapse due to osteoporosis or malignancy: appearance on unenhanced and gadolinium-enhanced MR images. Radiology. 1996;199:541–9.
25. Garfin SR, Buckley RA, Ledlie J. Balloon kyphoplasty for symptomatic vertebral body compression fractures results in rapid, significant, and sustained improvements in back pain, function, and quality of life for elderly patients. Spine (Phila Pa 1976). 2006;31:2213–20.
26. Gangi A, Sabharwal T, Irani FG, Buy X, Morales JP, Adam A, et al. Quality assurance guidelines for percutaneous vertebroplasty. Cardiovasc Intervent Radiol. 2006;29:173–8.
27. Kamath S, Venkatanarasimha N, Silver DAT. Percutaneous vertebroplasty. CPD J Radiol Update 2007; 6:82–96 and National institute for health and care excellence interventional procedures programme. Interventional procedure overview of percutaneous vertebroplasty (methyl methacrylate). London: NICE; 2003.
28. Blattert TR, Jestaedt L, Weckbach A. Suitability of a calcium phosphate cement in osteoporotic vertebral body fracture augmentation: a controlled, randomized, clinical trial of balloon kyphoplasty comparing calcium phosphate versus polymethylmethacrylate. Spine (Phila Pa 1976). 2009;34:108–14.
29. Kamath S, Venkatanarasimha N, Silver DAT. Percutaneous vertebroplasty. CPD J Radiol Update. 2007;6:82–96.

30. National Institute for Health and Care Excellence. Interventional procedure guidance 12: percutaneous vertebroplasty. London: NICE; 2003.
31. National Institute for Health and Care Excellence. Interventional procedure guidance 166: Balloon kyphoplasty for vertebral compression fractures. London: NICE; 2006.
32. Grohs JG, Matzner M, Trieb K, Krepler P. Minimal invasive stabilization of osteoporotic vertebral fractures: a prospective nonrandomized comparison of vertebroplasty and balloon kyphoplasty. J Spinal Disord Tech. 2005;18:238–42.
33. Grados F, Depriester C, Cayrolle G, Hardy N, Deramond H, Fardellone P. Long-term observations of vertebral osteoporotic fractures treated by percutaneous vertebroplasty. Rheumatology (Oxford). 2000;39:1410–4.
34. Lee HM, Park SY, Lee SH, Suh SW, Hong JY. Comparative analysis of clinical outcomes in patients with osteoporotic vertebral compression fractures (OVCFs): conservative treatment versus balloon kyphoplasty. Spine J. 2012;12:998–1005.
35. Yang EZ, Xu JG, Huang GZ, Xiao WZ, Liu XK, Zeng BF, Lian XF. Percutaneous vertebroplasty versus conservative treatment in aged patients with acute osteoporotic vertebral compression fractures: a prospective randomized controlled clinical study. Spine (Phila Pa 1976). 2016;41(8):653–60.
36. Rousing R, Hansen KL, Andersen MO, Jespersen SM, Thomsen K, Lauritsen JM. Twelve-months follow-up in forty-nine patients with acute/semiacute osteoporotic vertebral fractures treated conservatively or with percutaneous vertebroplasty: a clinical randomized study. Spine (PhilaPa 1976). 2010;35:478–82.
37. Shi-Ming G, Wen-Juan L, Yun-Mei H, et al. Percutaneous vertebroplasty and percutaneous balloon kyphoplasty for osteoporotic vertebral compression fracture: a metaanalysis. Indian J Orthop. 2015;49(4):377–87.
38. Cummings SR, Melton LJ. Epidemiology and outcomes of osteoporotic fractures. Lancet. 2002;359:1761–7.
39. Wang H, Sribastav SS, Ye F, et al. Comparison of percutaneous vertebroplasty and balloon kyphoplasty for the treatment of single level vertebral compression fractures: a meta-analysis of the literature. Pain Physician. 2015;18(3):209–22.
40. Wardlaw D, Cummings SR, Van Meirhaeghe J, Bastian L, Tillman JB, Ranstam J, Eastell R, Shabe P, Talmadge K, Boonen S. Efficacy and safety of balloon kyphoplasty compared with non-surgical care for vertebral compression fracture (FREE): a randomised controlled trial. Lancet. 2009;373:1016–24.
41. Kasperk C, Grafe IA, Schmitt S, Nöldge G, Weiss C, Da Fonseca K, Hillmeier J, Libicher M, Sommer U, Rudofsky G, Meeder PJ, Nawroth P. Three-year outcomes after kyphoplasty in patients with osteoporosis with painful vertebral fractures. J Vasc Interv Radiol. 2010;21:701–9.
42. Röllinghoff M, Siewe J, Zarghooni K, Sobottke R, Alparslan Y, Eysel P, et al. Effectiveness, security and height restoration on fresh compression fractures–a comparative prospective study of vertebroplasty and kyphoplasty. Minim Invasive Neurosurg. 2009;52:233–7.
43. Molloy S, Mathis JM, Belkoff SM. The effect of vertebral body percentage fill on mechanical behavior during percutaneous vertebroplasty. Spine (Phila Pa 1976). 2003;28(14):1549–54.
44. Hiwatashi A, Yoshiura T, Yamashita K, Kamano H, Dashjamts T, Honda H. Morphologic change in vertebral body after percutaneous vertebroplasty: follow-up with MDCT. AJR Am J Roentgenol. 2010;195:W207–12.
45. Hiwatashi A, Westesson PL, Yoshiura T, Noguchi T, Togao O, Yamashita K, Kamano H, Honda H. Kyphoplasty and vertebroplasty produce the same degree of height restoration. AJNR Am J Neuroradiol. 2009;30:669–73.
46. Feltes C, Fountas KN, Machinis T, Nikolakakos LG, Dimopoulos V, Davydov R, Kassam M, Johnston KW, Robinson JS. Immediate and early postoperative pain relief after kyphoplasty without significant restoration of vertebral body height in acute osteoporotic vertebral fractures. Neurosurg Focus. 2005;18:e5.
47. Klazen CA, Lohle PN, de Vries J, Jansen FH, Tielbeek AV, Blonk MC, Venmans A, van Rooij WJ, Schoemaker MC, Juttmann JR, Lo TH, Verhaar HJ, van der Graaf Y, van Everdingen

KJ, Muller AF, Elgersma OE, Halkema DR, Fransen H, Janssens X, Buskens E, Mali WP. Vertebroplasty versus conservative treatment in acute osteoporotic vertebral compression fractures (Vertos II): an open-label randomised trial. Lancet. 2010;376(9746):1085–92.
48. Huang Z, Wan S, Ning L, Han S. Is unilateral kyphoplasty as effective and safe as bilateral kyphoplasties for osteoporotic vertebral compression fractures? A meta-analysis. Clin Orthop Relat Res. 2014;472:2833–42.
49. Taylor RS, Fritzell P, Taylor RI. Balloon kyphoplasty in the measurement of vertebral compression fractures: an update systematic review and meta-analysis. Eur Spine J. 2007;16(8):1085–100.
50. McGirt MJ, Parker SL, Wolinsky JP, Witham TF, Bydon A, Gokaslan ZL. Vertebroplasty and kyphoplasty for the treatment of vertebral compression fractures: an evidenced based review of the literature. Spine J. 2009;9:501–8.
51. McCall T, Cole C, Dailey A. Vertebroplasty and kyphoplasty: a comparative review of efficacy and adverse events. Curr Rev Musculoskelet Med. 2008;1:17–23.
52. Choe DH, Marom EM, Ahrar K, Truong MT, Madewell JE. Pulmonary embolism of polymethyl methacrylate during percutaneous vertebroplasty and kyphoplasty. AJR Am J Roentgenol. 2004;183(4):1097–102.
53. FDA. Class II special controls guidance document: Polymethylmethacrylate (PMMA) bone cement: guidance for industry and FDA. 2011. URL: www.fda.gov/medicaldevices/deviceregulationandguidance/guidancedocuments/ucm072795.html.
54. Kim YY, Rhyu KW. Recompression of vertebral body after balloon kyphoplasty for osteoporotic vertebral compression fracture. Eur Spine J. 2010;19:1907–12.
55. Tanigawa N, Komemushi A, Kariya S, et al. Radiological follow-up of new compression fractures following percutaneous vertebroplasty. Cardiovasc Intervent Radiol. 2006;29:92–6.
56. Johannes H, Heiko F, Kerstin Wet al. Incidence of symptomatic vertebral fractures in patients after percutaneous vertebroplasty. Cardiovasc Intervent Radiol. 2006;29:92–6.
57. Micael NT, Susan MR, Frank MP, et al. Altered disc-pressure profile after an osteoporotic vertebral fracture in a risk factor for adjacent vertebral body fracture. Eur Spine J. 2008;17:1522–430.
58. Rohlmann A, Zander T, Bergmann G, et al. Spinal loads after osteoporotic vertebral fractures treated by vertebroplasty or kyphoplasty. Eur Spine J. 2006;15:1255–64.
59. Eck JC, Nachtigall D, Humphreys SC, Hodges SD. Comparison of vertebroplasty and balloon kyphoplasty for treatment of vertebral compression fractures: a meta-analysis of the literature. Spine J. 2008;8(3):488–97.
60. Hiwatashi A, Ohgiya Y, Kakimoto N, Westesson PL. Cement leakage during vertebroplasty can be predicted on preoperative MRI. AJR Am J Roentgenol. 2007;188(4):1089–93.
61. Anselmetti GC, Zoarski G, Manca A, Masala S, Eminefendic H, Russo F, Regge D. Percutaneous vertebroplasty and bone cement leakage: clinical experience with a new high-viscosity bone cement and delivery system for vertebral augmentation in benign and malignant compression fractures. Cardiovasc Intervent Radiol. 2008;31(5):937–47.
62. Hierholzer J, Fuchs H, Westphalen K, Baumann C, Slotosch C, Schulz R. Incidence of symptomatic vertebral fractures in patients after percutaneous vertebroplasty. Cardiovasc Intervent Radiol. 2008;31(6):1178–83.
63. Klazen CA, Venmans A, de Vries J, van Rooij WJ, Jansen FH, Blonk MC, Lohle PN, Juttmann JR, Buskens E, van Everdingen KJ, Muller A, Fransen H, Elgersma OE, Mali WP, Verhaar HJ. Percutaneous vertebroplasty is not a risk factor for new osteoporotic compression fractures: results from VERTOS II. AJNR Am J Neuroradiol. 2010;31(8):1447–50.
64. Campbell PG, Harrop JS. Incidence of fracture in adjacent levels in patients treated with balloon kyphoplasty: a review of the literature. Curr Rev Musculoskelet Med. 2008;1(1):61–4.
65. Taylor RS, Taylor RJ, Fritzell P. Balloon kyphoplasty and vertebroplasty for vertebral compression fractures: a comparative systematic review of efficacy and safety. Spine (Phila Pa 1976). 2006;31(23):2747–55.
66. Frankel BM, Monroe T, Wang C. Percutaneous vertebral augmentation: an elevation in adjacent-level fracture risk in kyphoplasty as compared with vertebroplasty. Spine J. 2007;7(5):575–82.

67. Belkoff SM, Mathis JM, Jasper LE, Deramond H. The biomechanics of vertebroplasty. The effect of cement volume on mechanical behavior. Spine (Phila Pa 1976). 2001;26(14):1537–41.
68. Kaufmann TJ, Trout AT, Kallmes DF. The effects of cement volume on clinical outcomes of percutaneous vertebroplasty. AJNR Am J Neuroradiol. 2006;27(9):1933–7.
69. Zheng Z, Luk KD, Kuang G, Li Z, Lin J, Lam WM, Cheung KM, Lu WW. Vertebral augmentation with a novel Vessel-X bone void filling container system and bioactive bone cement. Spine (Phila Pa 1976). 2007;32(19):2076–82.
70. Bae H, Shen M, Maurer P, Peppelman W, Beutler W, Linovitz R, Westerlund E, Peppers T, Lieberman I, Kim C, Girardi F. Clinical experience using Cortoss for treating vertebral compression fractures with vertebroplasty and kyphoplasty: twenty four-month follow-up. Spine (Phila Pa 1976). 2010;35(20):E1030–6.
71. Rauschmann M, Vogl T, Verheyden A, Pflugmacher R, Werba T, Schmidt S, Hierholzer J. Bioceramic vertebral augmentation with a calcium sulphate/hydroxyapatite composite (Cerament SpineSupport): in vertebral compression fractures due to osteoporosis. Eur Spine J. 2010;19(6):887–92.
72. Tomita S, Molloy S, Jasper LE, Abe M, Belkoff SM. Biomechanical comparison of kyphoplasty with different bone cements. Spine (Phila Pa 1976). 2004;29(11):1203–7.
73. Belkoff SM, Mathis JM, Deramond H, Jasper LE. An ex vivo biomechanical evaluation of a hydroxyapatite cement for use with kyphoplasty. AJNR Am J Neuroradiol. 2001;22(6):1212–6.
74. Ekman EF. The role of the orthopaedic surgeon in minimizing mortality and morbidity associated with fragility fractures. J Am Acad Orthop Surg. 2010;18(5):278–85.