Kyphoplasty: why, when and how?

Umile Giuseppe Longo [1,2], Rocco Papalia [1,2], Sergio De Salvatore [1,2], Valentina Piccioni [1,2], Vincenzo Denaro [1,2]

[1] Research Unit of Orthopaedic and Trauma Surgery, Fondazione Policlinico Universitario Campus Bio-Medico, Rome, Italy; [2] Research Unit of Orthopaedic and Trauma Surgery, Department of Medicine and Surgery, Università Campus Bio-Medico, Rome, Italy

ABSTRACT

Introduction: Percutaneous kyphoplasty (PKP) aims to restore vertebral shape and kyphotic spine angulation, reduce pain, and allow the patient early mobilization. Compared with percutaneous vertebroplasty (PV), PKP has been reported to reduce cement leakage, increase short-term pain relief, and improve kyphotic angle restoration. In addition, PKP has been shown to be a safe and effective method for treating non-responsive pain in osteoporotic vertebral compression fractures, and to allow shorter hospitalizations. This paper aims to review the current state of PKP, looking at the procedure itself, its use and complications, and how it compares with PV.

Surgical procedure: Precise placement of the inflatable balloons is required, and multiple processes must be completed before injecting the cement. A working cannula is inserted through the posterior wall of the vertebral body using a trans or parapedicular approach. Then, the balloons are inserted and inflated. Finally, the balloons are gradually removed, and polymethylmethacrylate is delivered through a blunt cannula. PKP has the same surgical indications and complications as PV. The main contraindications to PKP are unmanageable bleeding disorders, asymptomatic vertebral body fracture, allergy to bone cement, tumor mass with involvement of the spinal canal, unstable fractures or complete vertebral collapse, and neurological symptoms.

Conclusion: PKP and PV are both effective treatments for individuals with painful, acute compression fractures that have failed to respond to conventional treatment.

KEYWORDS

Spine, vertebroplasty, kyphoplasty, vertebral fracture, percutaneous, back pain.

Introduction

Percutaneous kyphoplasty (PKP) is an effective procedure used to restore vertebral height after a spinal fracture. During the procedure, two balloon catheters are introduced into the fractured vertebral bone and then expanded to recover the vertebral height. Then, polymethylmethacrylate (PMMA) is injected into the collapsed vertebral bodies [1]. This surgical procedure was developed in 1998 as a variation of the percutaneous vertebroplasty (PV) technique [2].

PKP aims to restore vertebral shape and kyphotic spine angulation, reduce pain, and allow the patient early mobilization [3]. It is often used in patients with acute osteoporotic vertebral compression fractures (OVCFs) [4].

OVCFs are the most common complication of osteoporosis. This fracture type can result in severe physical impairments, back pain, and functional limitations. Moreover, OVCFs progress over time and the compensatory increase in axial load may promote compression of the surrounding vertebrae [5,6]. Not all OVCFs are clinically significant, but 30% of symptomatic patients may suffer from chronic pain and progressive kyphosis, reducing their quality of life. The conservative management of symptomatic OVCFs includes rest, NSAIDs, muscle relaxants, bracing and physiokinesitherapy [7,8]. In the United States, 750,000 vertebral fractures are caused by osteoporosis every year; however, few studies have reported the incidence of OVCFs [9], which result in 150,000 yearly hospitalizations [10]. Mortality of OVCFs increases with the number of fractures. Kado *et al*. reported that female patients with one or more OVCFs showed a 1.23-fold greater age-adjusted mortality rate [11]. Moreover, patients with severe OVCFs reported an even greater increase in mortality rate (1.34-fold) [11]. Edidin *et al*. reported that treatment of OCVFs could reduce the mortality rate [12]. Patients treated with PKP had a 44% greater life expectancy than untreated patients. In addition, PKP patients had a 34% higher life expectancy rate compared with PV ones [12].

Compared with PV, PKP has been reported to reduce cement leakage, increase short-term pain relief, and improve kyphotic angle restoration [13]. Despite its advantages, PKP involves a longer operation time and increased costs [14,15]. In addition, the type of fracture, the localization, and the severity of the injury influence its outcomes [16].

PV is a common procedure performed worldwide. In Italy, an incidence of 8.8 procedures for every 100,000 inhabitants has been estimated [17].

On the contrary, PKP is less performed than PV and its incidence is not fully reported in the international literature. PKP has been shown to be a safe and effective method for treating

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Contact
Umile Giuseppe Longo; g.longo@policlinicocampus.it
Tel.: +39 06 225411613; Fax: +39 06 225411638

non-responsive pain in OVCFs, and to allow shorter hospitalizations, increasing the patient's quality of life [18]. This paper aims to review the current state of PKP, looking at the procedure itself, its use and complications, and how it compares with PV.

Surgical procedure

PKP is usually performed under general anesthesia. Precise placement of the inflatable balloons is required, and multiple processes must be completed before injecting the cement. Antibiotic prophylaxis is achieved by administering 1g of intravenous cefazolin 1 hour pre-surgery [19].

The most used surgical approaches are transpedicular or parapedicular [20]. A working cannula is inserted through the posterior wall of the vertebral body. PKP is accomplished using biplanar fluoroscopy or a computed tomography (CT) scan, and it might involve one or two pedicles from the same vertebrae. Depending on the vertebral level being approached, the starting point is usually at the superior lateral edge of the pedicle, with different angulation. To prevent injury to nerve roots and the spinal cord, the medial and inferior walls of the pedicle must be clearly visible. The C-arm is switched to the anteroposterior and lateral view to check the trajectory, and the PKP device is moved further, care being taken not to cross the medial pedicle wall. Once the posterior vertebral body has been accessed, the PKP device can be moved medially and distally. The tip of the needle should be inserted as close to the midline as possible in the anterior to the middle part of the vertebral body [21].

Two working channels are created inside the vertebral body using reaming devices. Then, the balloons are introduced and centered between the two endplates in the anterior part of the vertebral body. Finally, the balloons are inflated under fluoroscopic control to reduce the fractured vertebra, elevate the endplates, and create a cavity.

Inflation is stopped when vertebral pressure is above 13.8 bar; balloons come into contact with the endplates; if vertebral height is recovered, the balloons expand over the border of the vertebral body. The balloons are gradually removed, and PMMA is delivered through a blunt cannula under constant fluoroscopic supervision. The cost of the materials for a single-level kyphoplasty is around 4000 USD [22].

Indications

PKP has the same surgical indications and complications as PV [9]. For this reason, PKP is commonly adopted to treat OVCFs, myeloma, metastasis and vertebral angioma non-responsive to conservative treatments [8]. Radiographs, CT or magnetic resonance imaging are required to confirm the diagnosis of vertebral fractures.

Patients with multiple myeloma or spinal metastases are commonly affected by a spinal fracture because of bone loss. Non-responsive pain and neural compression are common symptoms of these conditions. In several cases, the vertebral fractures are accompanied by neurological impairment. In patients with cancer, physical function improvement may reduce comorbidities associated with prolonged immobility, such as thromboembolic events, pneumonia, and pressure sores [23,24]. Therefore, vertebral augmentation with kyphoplasty represents an effective solution to allow patients to walk early.

Contraindications

The main contraindications to PKP are unmanageable bleeding disorders (coagulation disorders), asymptomatic vertebral body fracture, allergy to bone cement, tumor mass with involvement of the spinal canal, unstable fractures or complete vertebral collapse (vertebra plana), and neurological symptoms [5]. In addition, the surgery should not be performed if there are ongoing local or systemic infectious processes, such as osteomyelitis or discitis. Fracture extension into the posterior vertebral body wall might result in cement extravasation into the spinal canal, and severe compression fractures are relative contraindications [21].

Complications

Severe general complications that could occur in the 30-day post-operative period are deep surgical site infection, sepsis, unexpected reintubation, perioperative renal failure, deep vein thrombosis, pulmonary embolism, heart attacks, or ischemic stroke. The rate of these types of complications is 4.3% [5].

Other complications can include infections, wound dehiscence, pneumonia, urinary tract infection, and postoperative renal insufficiency [5]. The rate of these types of complications ranges from 3.5% to 6.6% [5]. The risk is higher in patients between 80 and 89 years of age and appears to be due to a higher rate of pneumonia and urinary tract infections in this age group [5]. Specific complications following kyphoplasty procedures include medical and anesthetic complications, cement leakage, adjacent compression fractures, and infection.

In PKP, leakage occurs in 9% of cases and can lead to accumulation of particles in the veins with the potential risk of these particles embolizing in the lungs. In addition, PKP could alter the biomechanics of the vertebral segments, increasing the risk of adjacent compression fractures [25,26]. However, this finding remains controversial. Taylor *et al*. [27] reported a lower incidence of adjacent vertebral fracture in patients treated with PKP versus PV. Furthermore, the high temperature of the cement during polymerization could cause thermal injury to the paravertebral tissues [22].

Fissuration of the endplate may occur when the balloon is inflated, resulting in cement extravasation into the intervertebral space. Cement leakage into the epidural space can cause iatrogenic spinal stenosis with dramatic neurological consequences [21]. Therefore, careful assessment of the risk of bleeding can help prevent a potentially fatal spinal hematoma or hemorrhage.

The success rate of kyphoplasty in restoring vertebral body height ranges from 0% to 90%.

Discussion

In elderly patients with symptomatic OVCFs, PKP and PV are treatments frequently considered. Both PKP and PV have been shown to have beneficial effects in selected patient populations [21].

A recent systematic review and meta-analysis compared PV with PKP surgeries in a cohort of 2838 individuals (1454 PV and 1384 PKP). Chandra et al. reported no differences in back pain or disability scores between the two procedures at any follow up. In addition, although there was no difference in the rate of symptomatic cement leakage, in PKP patients a lower overall cement leakage rate was recorded. Moreover, PKP provided better kyphosis restoration [18]. However, several clinical trials reported different results regarding PKP outcomes. Table 1 summarizes the essential data in the literature on PKP.

Conclusion

PKP and PV are both effective treatments for individuals with painful, acute compression fractures that have failed to respond to conventional treatment. However, further high-quality clinical trials are required to prove the effectiveness and safety of PKP and PV compared with other procedures.

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Table I Summary of recent evidence of Kyphoplasty in the literature.

EARLY OBSERVATIONAL DATA	
Jensen *et al.* 1997 [28]	29 patients treated with vertebroplasty 90% pain relief after vertebroplasty in 24 hours
Hochmuth *et al.* 2006 [29]	2086 patients treated with vertebroplasty VAS score significantly reduced
Bouza *et al.* 2006 [30]	1710 patients treated with kyphoplasty VAS score reduced in both groups (vertebroplasty and kyphoplasty)
EARLY RANDOMZED CONTROLLED TRIALS	
The Vertebroplasty for Painful Chronic Osteoporotic Vertebral Fractures (VERTOS) trial [31]	**First RCT, published in 2007** Vertebroplasty vs medical management 34 patients included VAS score at 24 hours was improved after vertebroplasty VAS score improvement no longer significant at two weeks
The Fracture Reduction Evaluation (FREE) trial in 2009 [32]	Kyphoplasty vs medical management 300 patients included NRS improved for two years SF-36 improved in the first months but decreased at two years of follow up
The Investigational Vertebroplasty Safety and Efficacy Trial (INVEST) - August 2009 [33]	131 patients Vertebroplasty vs sham **No differences between cases and controls in VAS and RDQ scores**
RECENT PROSPECTIVE RANDOMIZED CONTROLLED DATA	
The Vertebroplasty for Acute Painful Osteoporotic Fracture (VAPOUR) trial – 2016 [34]	Early vertebroplasty vs sham 120 patients included VAS and RDQ scores improved in the first six months in the vertebroplasty group
UPCOMING EVIDENCE	
VERTOS IV [35] and VERTOS V [36] started	Both studies comparing vertebroplasty to sham

VAS=visual analog scale; **NRS**=numeric rating scale; **SF-36**= Short-Form-36; **RDQ**=Roland Morris Disability Questionnaire.

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