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REVIEW

Controversial Issues in Cementoplasty

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ABSTRACT

Vertebroplasty and kyphoplasty are effective in controlling pain and improving daily activities with sustained results. Kyphoplasty improves vertebral body height and kyphosis. These benefits and demonstrable improvement in quality of life in elderly patients support the prompt cementoplasty management of osteoporotic vertebral compression fractures (OVCFs). The magnitude of pain reduction is not always dependent upon the interval between fracture and surgery. Evidence of nonhealing on MRI and the degree of persistent pain should be determinative factors in patient selection. This paper reviews advantages and disadvantages of kyphoplasty and vertebroplasty and identifies major clinical issues associated with these treatment options reported in the literature.
Level of Evidence: V; Descriptive review/Expert opinions.
Keywords: Vertebroplasty; Kyphoplasty; Complications; Cost effectiveness.

INTRODUCTION

Since their inception, both vertebroplasty, introduced in the mid-80s [1], and balloon kyphoplasty, introduced in the late 90s [2], have become widespread methods for the treatment of osteoporotic vertebral compression fractures (OVCFs) and osteolytic tumors. However, by 2009, kyphoplasty and particularly vertebroplasty had been challenged as ineffective procedures by 2 randomized controlled trials (RCTs) published in the New England Journal of Medicine (NEJM) [3,4]. These 2 studies suggest that vertebroplasty is not significantly different to placebo. These assertions were widely accepted, reducing the practice of cementoplasty as they compared the procedure to a sham surgery under the same operating and anesthetic conditions. Widespread debate has ensued suggesting vertebroplasty is expensive and ineffectual. In September 2010, the American Academy of Orthopaedic Surgeons (AAOS) issued a strong recommendation against vertebroplasty and a weak recommendation for kyphoplasty [5]. Subsequently, an editorial in the NEJM Journal Watch by Brett concluded that selective and limited use of vertebroplasty is acceptable as long as the clinician shares uncertainty about the procedure's effectiveness with the patient

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and intervention should be performed neither too early nor too late [6].

An extensive debate among critics has followed in the medical community raising serious concerns regarding the 2 RCTs and questioning their scientific integrity with regard to selection of patients with high patient refusal rate, lack of statistical power with high "sham group" crossover, treatment methodology, failure to analyze fracture type subgroups, and inclusion criteria with low pain scores [7-9]. This review addresses these issues.

Age of fracture is a disputable factor. Contrary to reports indicating treatment response is not related to the age of fracture [10], more recent studies demonstrate that older fractures do not respond as well with vertebroplasty [11]. These 2 RCTs could have been stratified or perhaps limited to acute fractures. Aebi [9] has remarked that the character of the back pain should have been defined. Pain associated with OVCFs should be differentiated from facetogenic arthritic pain that can worsen or become provoked by segmental OVCF-related kyphosis that renders the spinal segment unstable. This pain may respond well with lasting effect [12] to facet-joint local anesthesia [13] or radiofrequency ablation. Rapid pain relief, after vertebroplasty and sham procedure alike, may result from the therapeutic response of the local anesthesia around the facet joint and not the placebo effect [8].

The effective amount of cement injected is questionable. Fill volumes of at least 13%–16% of vertebral volume in 1 study and 24% in another are considered optimal for restoration of vertebral body strength [14,15]. A poly(methyl methacrylate) (PMMA) volume of 3 mL in the thoracolumbar spine in the Buchbinder study (no published cement data are available in the Kallmes study) instead of at least

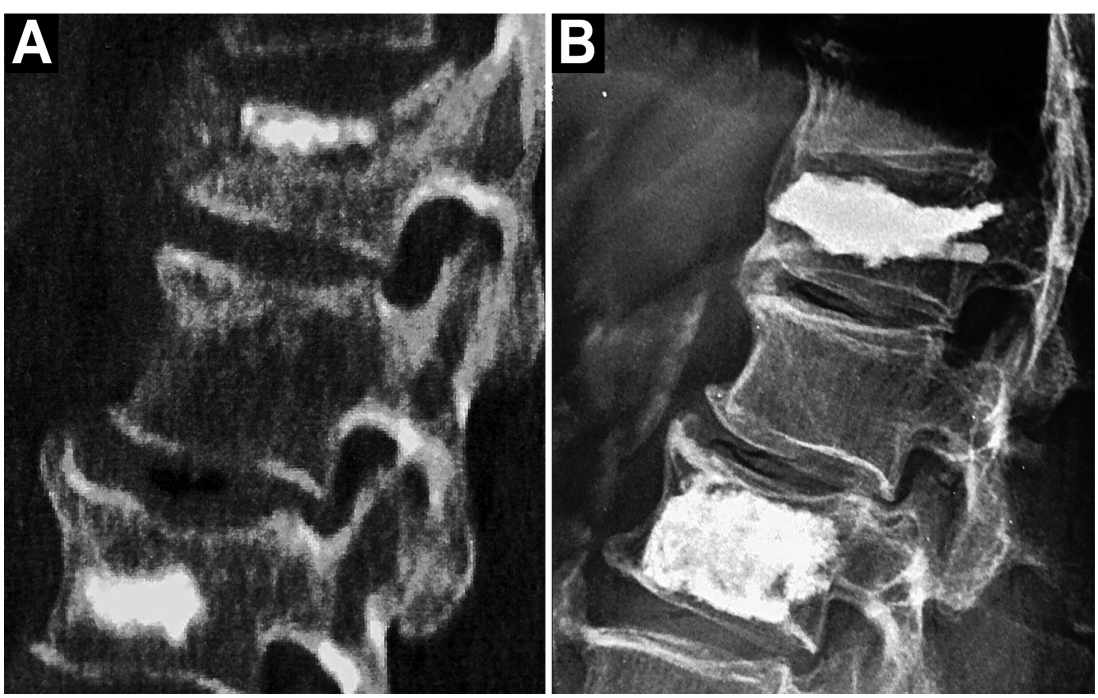

Figure 1. A 55-year-old male patient with a 3-month intractable back pain (VAS: 8/10) with OVF underwent an inadequate amount cement vertebroplasty (**A**). The symptoms remained unabated and following revision kyphoplasty, the patient felt an immediate and sustained relief of pain (VAS: 0/10) at 5 year follow-up (**B**). Note the pseudarthrotic cleft of the L1 vertebra (**A**) and cement interdigitation in the vertebral body (**B**).

4 mL can be considered inadequate for instituting optimal strength to axial loading [8]. Furthermore, the authors successfully revised 5 patients with failed painful cementoplasty, due to insufficient cement volume, with kyphoplasty in the lumbar spine (Figure 1).

The inclusion pain score was 3 out of 10 allowing the authors to recruit more patients. No mention was made by the authors as to why patients refused randomization. Pain severity may have influenced their decision-making [7,8,16]. It has been argued that both RCTs were underpowered (131 patients in 1 study and 78 in the other), with difficulty enrolling an adequate population sample. A substantial number of patients crossed over from the sham procedure to vertebroplasty.

It is of interest in these 2 RCTs that a subset of patients with pseudarthrosis and kyphosis (in particular patients on steroids), which are notoriously refractory to conservative treatment, were not included (Figure 2). These patients responded very well to kyphoplasty. Furthermore, it is well known [17] that a group of patients with osteoporotic fractures or pseudarthrosis may lead to crippling, painful kyphotic deformity (even while on conservative treatment) with potential neurologic deficit. These complications lead to major surgical intervention [18].

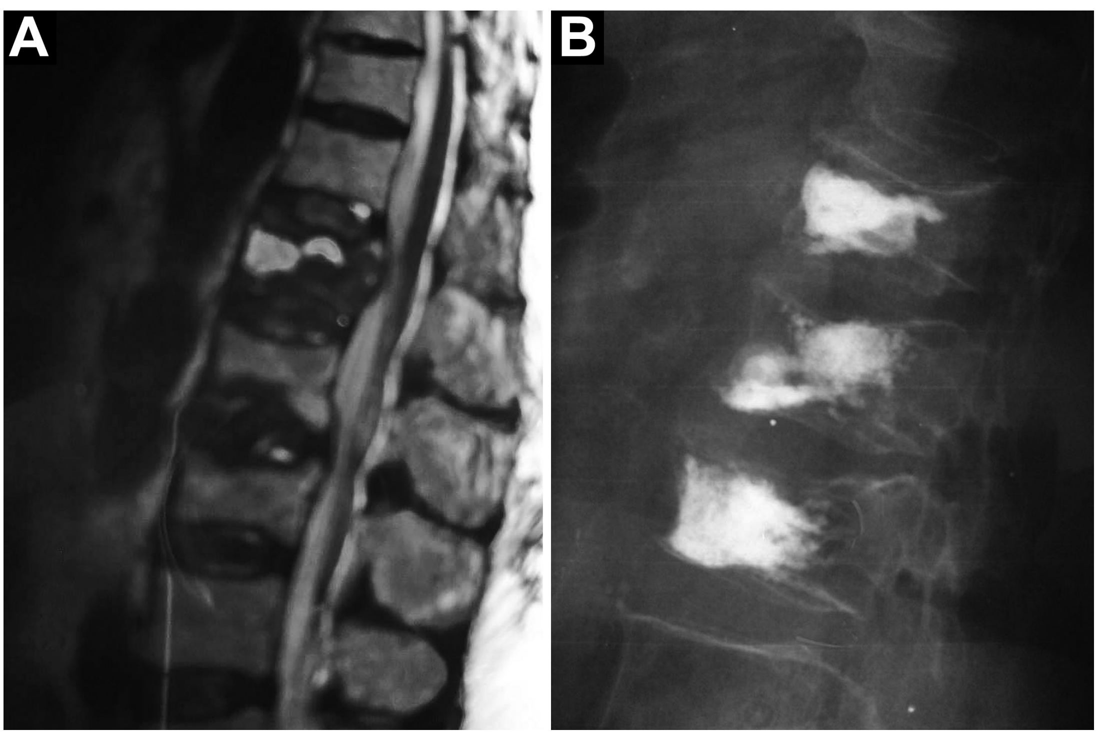

Figure 2. On MRI T2 weigh image (**A**), the OVFs nonunion is described as a high intensity signal of distinct focal cleft filled with fluid. During kyphoplasty the confinement of the cavity was disrupted with special osteotome in order to allow the cement to interdigitate with the trabeculae (**B**).

Comparing a surgical procedure to a sham procedure performed in an ethical fashion and well controlled is valuable. The degree of confidence, however, of these two RCTs is questionable as there are demonstrable flaws which should be evaluated further. Mandates and recommendations based on inadequate scientific evidence are currently being made and are unfortunately influencing decision-making regarding geriatric patients who could benefit from a reduction in pain and disability and improvement in quality of life through appropriate intervention. Clinical decision-making algorithms (guidelines) should include studies with incontrovertible scientific thoroughness and rigor based on large stratified population samples and continuously updated and modified based on the evidence.

MATERIALS & METHODS

We performed a literature search using PubMed database with the following keywords: osteoporotic vertebral compression fractures, vertebroplasty, kyphoplasty, and cementoplasty. The most recent pertinent papers discussing complications related to OVCF, cement, and surgical technique were analyzed. RCTs comparing outcomes of vertebroplasty, kyphoplasty, and conservative treatment are examined.

RCTs

A recent, randomized double-blind placebo controlled trial by Clark et al. supported the effectiveness of vertebroplasty [19]. In this study, the authors demonstrated the immediate and 6 month sustained improvement with vertebroplasty in contrast to a sham procedure in a well controlled experiment. Some of the objections leveled at the previous control trials were addressed in this study which limited the selection of patients to an inclusion pain score of 7 or more out of 10 and an average volume of injected cement per segment of 7.5 mL (SD=2.8). It is of interest to underscore in this study the incidence of 3.3% (2 patients out of 79) of spinal cord compression from progressive vertebral body collapse in the control group. These cases highlight the risks associated with painful OVCFs.

In this context, several RCTs demonstrate the benefit of vertebroplasty or kyphoplasty over traditional conservative therapy (Table 1). There was no statistically significant difference of pain relief or disability between vertebroplasty and kyphoplasty [47,48]. Kyphoplasty demonstrated improvement of kyphotic angulation [49-51] and less cement leakage [52]. It is of interest that although some studies showed pain relief was similar between vertebroplasty and kyphoplasty, the functional improvement was better in kyphoplasty [53-55]. Since one expects pain relief to parallel the quality of life improvement, these results are obfuscating.

Clinical Indications for Cementoplasty

Osteoporotic Fractures

OVCFs, despite their ubiquitous nature, can give rise to complications, such as chronic back pain, disabling deformity, reduced pulmonary function, restriction for the abdominal and thoracic organs, pseudoarthroses, neurological complications and clinical depression [56,57]. Kyphoplasty is not the first line treatment for OVCFs. OVCFs can respond satisfactorily to conservative treatment including bed rest, analgesics, bracing, antiosteoporotic medication, or some combination of the above [58].

The primary indication for a cementoplasty procedure is severe, persistent pain at the level of the fracture site refractory to conservative treatment [59] and concomitant disability. Pain to palpation at the fracture site spinous process is a reliable test indicating pain-generating pathology [60].

The optimal intervention procedure time is debatable. Studies generally support earlier intervention [33], though satisfactory results have also been reported in later intervention [61]. The majority of acute OVCFs improve in the first 3 months, and early intervention may not be necessary; however, a late intervention may lead to an unfavorable outcome. Papanastasiou et al. proposed a therapeutic "window" of 7 weeks, with an exception of prompt intervention when progression of the wedging vertebral is detected in the thoracic spine [62]. In a retrospective study, 99 patients were divided into 3 groups to evaluate the results of balloon kyphoplasty performed at different times after injury. Patients in all 3 groups displayed significant pain relief [63].

Pseudoarthrosis – Kummell's disease

Another indication for cement augmentation procedures is the presence of painful pseudoarthrosis complicating OVCFs as a result of osteonecrosis [64]. A variety of terms have been used to describe this pathology: intervertebral vacuum, cleft, delayed vertebral collapse, vertebral non-union [65]. Herman Kummell first described this entity in 1895 as a posttraumatic delayed collapse of the vertebral body resulting from osteonecrosis [64]. He postulated that even minimal trauma can cause damage to the nutrient vessels which sets in motion delayed collapse of the trabeculae and leads to nonunion [65]. After OVCF, persistent mobility may lead to cleft formation and release of vacuum gas within the cracks of the subchondral bone which may contribute to nonunion. Subsequently, the gas-filled cleft fills with fluid and necrotic granulation tissue, resulting in a characteristic MRI image [66]. Alcohol consumption, radiotherapy, and steroids have been identified as contributing factors [67]. Incidence is estimated to range between 7%–37% [68] and may be noted after 6 months of conservative treatment [69].

The disease may result in sequelae, such as severe kyphosis and extrusion of a posterior bony fragment into the canal. This may compromise the neural elements of the spinal canal resulting in neurologic deficit [66]. Treatment options must take into account 3 main factors: the patient's symptoms, the degree of the kyphotic deformity, and the presence of neurologic deficit [70]. Conservative treatment with bracing and analgesics can be ineffective and is contraindicated in the presence of spinal cord compression [71] (Figure 3).

As the majority of patients are of an advanced age, many authors have recommended minimal procedures, such as cement augmentation alone [72,73] or in combination with short segmental fixation as safe and effective management [74] (Figure 4). Cement augmentation alleviates pain and prevents further collapse of the vertebral body. Li and others recommend a more extended procedure if there is a severe kyphotic deformity [75,76]. Patients with severe spinal stenosis and cord compression without neurologic deficit can benefit from kyphoplasty as a stand-alone procedure. In this instance, the cement-inserting cannula must be placed into the cleft at the anterior 2/3 of the vertebral body, dynamic monitoring during cement filling is recommended, and the cement should be infused slowly in a very doughy state [77]. In a recent cohort study of 1-level Kummell's disease, 12 patients, although initially displaying significant improvement of pain and deformity correction, at 6 months exhibited variable degrees of kyphotic deformity and pain [78]. Inadequate interdigitation of cement into the trabeculae is attributed to the insufficient outcome that particularly occurs with vertebroplasty. This complication may be overcome by using a special

Table 1. Studies comparing cement augmentation (kyphoplasty, vertebroplasty) vs conservative therapy in OVCF patients.

Authors, Year [ref]	Study	Follow-up	Treatment	Patients (N)	VAS reduction	Functional improvement
Chen et al, 2014 [20]	RCT	12m	VB/CT	46/50	VB>CT	ODI: VB>CT
Blasco et al, 2012 [21]	RCT	12m	VB/CT	64/61	Faster improvement VB=CT long term	QUALEFFO: VB>CT short term VB=CT long term
Farrokhi et al, 2011 [22]	RCT	36m	VB/CT	40/42	VB>CT	VB>CT
Alvarez et al, 2006 [23]	CCT	3m-12m	VB/CT	101/27	Early: VB>CT	Early: VB>CT
Diamond et al, 2006 [24]	CCT	6w-24m	VB/CT	88/38	Early: VB>CT No difference at 6m	Early: VB>CT No difference at 6m
Klazen et al, 2010 [25] VERTOS II	RCT	1w-12m	VB/CT	101/101	VB>CT	EQ-5D, RMD: VB>CT
Rousing et al, 2009 [26,27]	RCT	3m-12m	VB/CT	25/25	Early: VB>CT VB=CT at 12m	SF-36 Early: VB>CT; VB=CT at 12m
Kallmes et al, 2009 [4]	RCT	1m	VB/Sham	68/63	VB=Sham	EQ-5D: VB=Sham
Buchbinder et al, 2009 [5]	RCT	6m	VB/Sham	38/40	VB=Sham	EQ-5D: VB=Sham
Voormolen et al, 2007 [28] VERTOS I	RCT	2w	VB/CT	18/16	VB>CT	QUALEFFO: VB>CT
Kroon et al, 2014 [29]	RCT	12m, 24m	VB/Sham	38/40	VB=Sham	VB= Sham
Comstock et al, 2013 [30]	RCT	12m	VB/Sham	68/63	VB>Sham (modest)	RDQ: VB=Sham
Clark et al, 2016 [19]	RCT	6m	VB/Sham	61/59	VB>Sham	RDR, SF-36, QUALEFFO: VB>Sham
Yang et al, 2016 [31]	RCT	12m	VB/CT	56/61	VB>CT	QUALEFFO: VB>CT

Table 1 *cont*. Studies comparing cement augmentation (kyphoplasty, vertebroplasty) vs conservative therapy in OVCF patients.

Authors, Year [ref]	Study	Follow-up	Treatment	Patients (N)	VAS reduction	Functional improvement
Wardlaw et al, 2009 [32]	RCT	1m	KP/CT	149/151	KP>CT	SF-36: KP>CT
Grafe et al, 2005 [33]	CCT	12m	KP/CT	40/20	KP>CT	EVOS: KP>CT
Kasperk et al, 2005, 2010 [34,35]	CCT	6m-36m	KP/CT	40/20	KP>CT	EVOS: KP>CT
Boonen et al, 2011 [36]	RCT	24m	KP/CT	149/151	KP>CT	SF-36: KP>CT
Xie et al, 2011 [37]	RCT	9m	KP/CT	77/42	KP>CT	SF-36: KP>CT
Grohs et al, 2005 [38]	CCT	24m	KP/VB	28/23	VB=KP	ODI: VB=KP (No changes from pre-op)
Liu et al, 2010 [39]	RCT	6m	KP/VB	50/50	VB=KP	
Lovi et al, 2009 [40]	CCT	36	KP/VB	36/118	VB=KP	VB=KP
De Negri et al, 2007 [41]	CCT	6m	KP/VB	21 total	VB=KP	VB=KP
Bae et al, 2010 [42]	RCT	24m	KP/VB	20/20	VB=KP	VB=KP
Kumar et al, 2010 [43]	CCT	42w	KP/VB	24/28	VB=KP	VB=KP
Röllinghoff et al, 2009 [44]	CCT	12m	KP/VB	90 total	VB=KP	VB=KP
Santiago et al, 2010 [45]	CCT	12m	KP/VB	30/30	VB=KP	VB=KP
Schofer et al, 2009 [46]	CCT	12m	KP/VB	30/30	VB=KP	VB=KP
Dohm et al, 2014 [47]	RCT	24m	KP/VB	191/190	VB=KP	VB=KP

OVCF, osteoporotic vertebral compression fracture; VB, vertebroplasty; PK, kyphoplasty; CT, Conservative therapy; RCT, randomized control trial; CCT, clinical control trial.

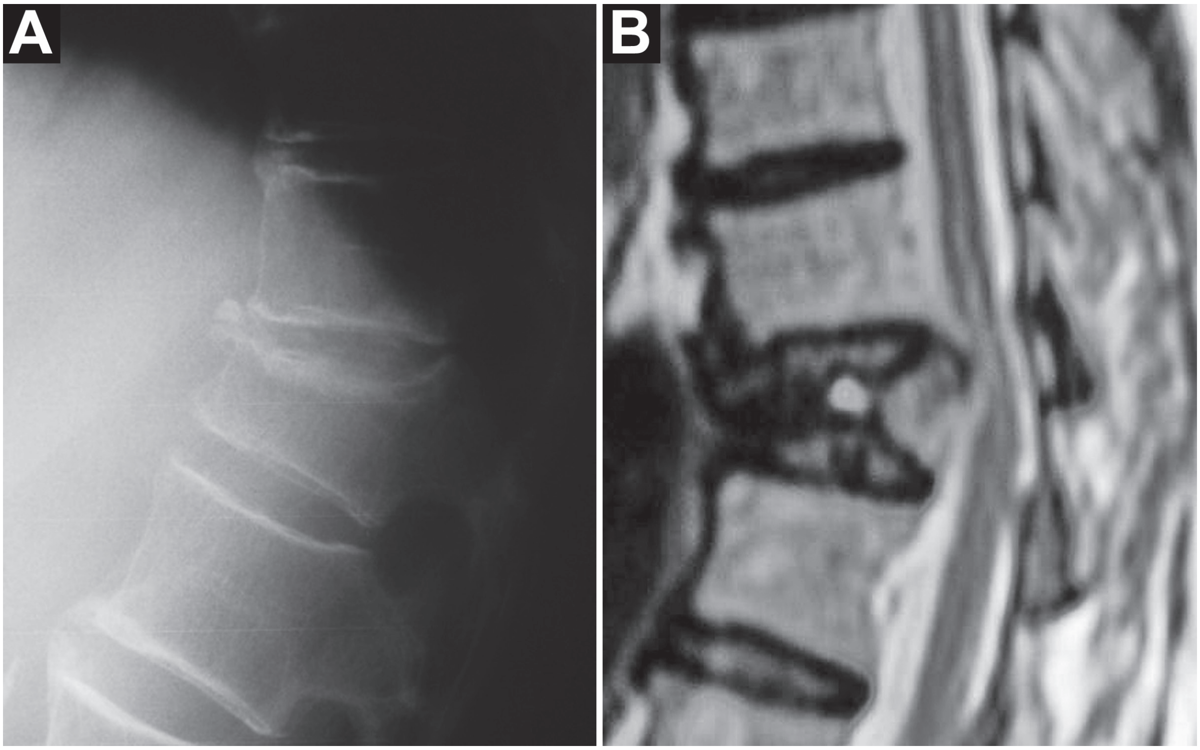

Figure 3. Delayed collapse of pseudarthrotic wedge fracture complicated with kyphosis, retropulsion of posterior vertebral wall fragment and paraparesis. This could have been prevented with kyphoplasty. **(A)** plain X-rays; **(B)** MRI scan.

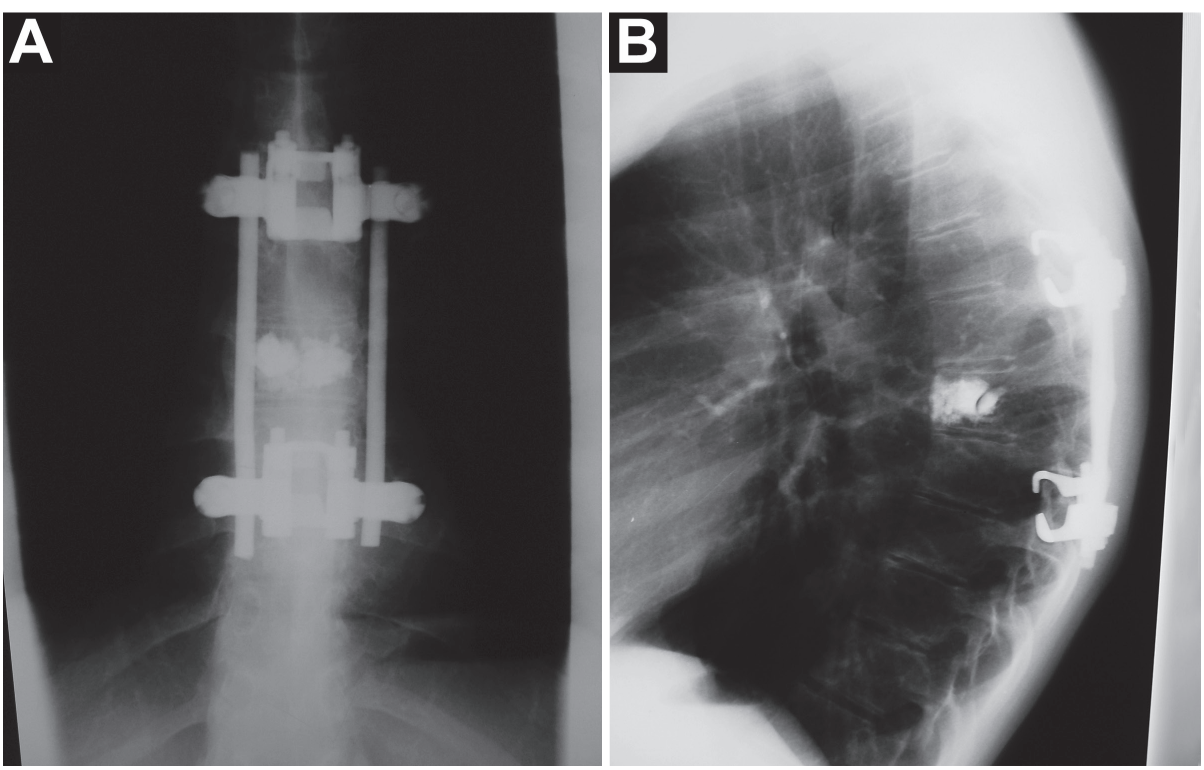

Figure 4. Kyphoplasty and posterior instrumentation for the treatment of an OVCF complicated with pseudarthrosis and kyphosis. **(A)** AP view; **(B)** lateral view.

kyphoplasty osteotome (KYPHON Latitude II™ Curette, 8.0mm T-tip; Medtronic, Minnesota, MN, USA) to break the sclerotic margins of bone surrounding the osteonecrotic cavity. Following this, a KYPHON flat balloon is inserted as there is reduced height of the vertebral body, and the cement is inserted slowly in a more viscous state and interdigitates with the trabecular bone.

Cement Leakage

A potentially harmful event of cement augmentation procedures is PMMA cement leakage. The cement may extravasate locally into the spinal canal, the intervertebral disk space, the foramina, or the paravertebral space or migrate distally through the epidural or vertebral venous system. Although cement leakage is well tolerated in the majority of cases, it is a cause of pulmonary and neurological complications [79] which can be catastrophic. An advantage of kyphoplasty over vertebroblasty is the creation of a cavity by the balloon which allows a viscous cement injection under reduced pressure. In addition, the balloon tamp compacts the trabecular bone which may seal potential osseous or venous leak pathways [80].

The risk of cement leakage during augmentation, as reported in a systematic review, ranges from 2.7%–26.3% with kyphoplasty, as demonstrated on fluoroscopic studies, and an incidence of cement leakage with vertebroplasty ranging from 11.7%–71.4% [17,81]. CT studies show an incidence 22.5%–87.5% [81] with vertebroplasty. This echoes Yeom et al. CT study that cement leakage is more frequently observed on CT than radiographs [82], suggesting that the incidence of cement leakage observed during surgery is underestimated as seen on plain fluoroscopy. Cement leakages were classified into 3 types: through the basivertebral vein (type B), through the segmental vein (type S), and through a cortical defect (type C) [82].

Cement extravasation is related to the viscosity of the cement, the injection pressure, and the amount of cement [2,83-86]. It has also been reported that the rate of cement leakage is related to the timing of the procedure [63]. In the fracture acute phase (less than 7 weeks), cracks in the cortex increase the risk of cement extravasation. In late intervention, the healing process may reduce diffusion of cement, but require cement to be injected under higher pressure which also may promote cement leakage [63].

Cement leakage is significant. Using proper surgical technique, the incidence of cement leakage can be markedly reduced. Correct placement of the balloon, cement viscosity, constant fluoroscopically controlled cementation, and proper cement volume minimize the risk of cement leakage. Recent reports advocate that sufficient cement volume to restore vertebral strength and achieve good clinical outcome should be substantial [87] as opposed to earlier reports that small cement volumes are adequate [88].

A technique called "egg shell" has been promoted to prevent cement leakage when the vertebral confinement is violated. [60,89]. In this instance, if a compromised vertebral wall is identified, the balloon should be immediately removed, followed by 1cc cement deployed and the reinsertion of the balloon into the injected cement. At this stage, the inserted balloon is reinflated until it abuts the compromised vertebral wall which seals the defect. The cement is allowed to harden, the balloon is removed, followed by a conventional kyphoplasty [60] (Figure 5).

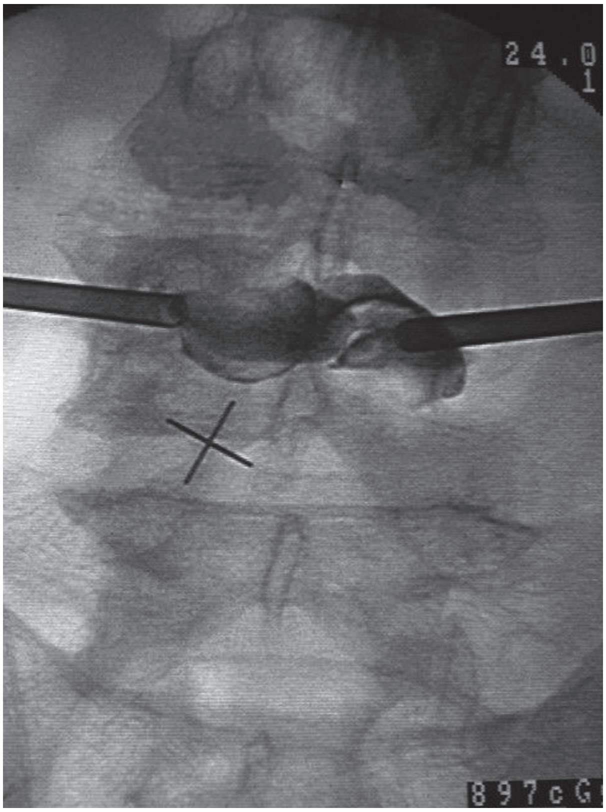

Figure 5. The egg shell technique. A thin shell of bone cement surrounds the expanding balloon.

Respiratory Effects and Hemodynamic Changes

Hemodynamic and respiratory complications, such as transient hypotension and degrease of oxygen saturation, have been widely reported during cement augmentation procedures. The exact incidence is not clear. The incidence may be underestimated as a respiratory decline during surgery in a geriatric patient may be attributed to preexisting pulmonary disease [90]. Cement embolism can be asymptomatic or symptomatic and presents with dyspnea, tachypnea, tachycardia, cyanosis, chest pain, coughing, and hemoptysis [91]. Aebli et al., in several animal studies, using different materials, showed that cement and fat embolism can cause serious cardiopulmonary deterioration during cement augmentation procedures [92-94]. Pulmonary embolism is correlated to an increased interosseous pressure during the procedure which forces fat, bone marrow, and PMMA particles into the epidural and vertebral venous system. There is also a decline of sympathetic tone associated with this process rather than to cement toxicity itself [95]. The viscosity and the amount of cement injected is a significant factor related to cement extravasation. Evidence supports this finding [86]. Some authors recommend against injecting more than 30 mL or more than 3 levels per session [96]. Augmentation of multiple levels has also been blamed for cardiovascular complications associated with simultaneous inflation of multiple balloons or simultaneous injection of multiple levels [83].

Intracardiac cement leakage is an extremely rare complication following kyphoplasty and vertebroplasty. There are only a few cases reported in the literature [97-99]. The consequences of intracardiac cement embolism are perforation of myocardium, pericardial tamponade, or pericardial perforation, which may cause chest pain, dyspnea, and shock [98]. Open heart surgery or catheterization is necessary in order to remove the cement fragment [99].

Some methods have been used to minimize the risk of cardiovascular and pulmonary complications during kyphoplasty, particularly when undertaking a multiple level procedure [83]. There are considerations during patient positioning and anesthesia preparation. Patient prone position during surgery affects intra-abdominal (increased inferior vena cava pressure), along with intrathoracic, and intraosseous vertebral body pressures [100]. Higher venous pressure results in safer cement insertion by avoiding risks, such as fat, bone marrow, or cement embolization [101]. During general anesthesia, a transient elevation of intrathoracic and intra-abdominal pressures can be achieved when inflating the balloons or inserting the cement to minimize pulmonary embolism. Multilevel (over 3 levels) cement-balloon kyphoplasty can be safely executed under proper surgical and anesthetic technique [83]. Optimal balloon placement, positive pressure ventilation during balloon inflation, and cement filling with very slow insertion, more of highly viscous cement in the vertebral body under constant imaging control minimize the risk of local and intravascular cement leakage and embolic complications. Close cardiorespiratory monitoring is also mandatory. Cement injection should be terminated if cement leakage is detected during fluoroscopy [102]. Standard therapeutic protocol for pulmonary cement embolization has not been described. In general, treatment is not suggested for asymptomatic patients with small peripheral emboli. In the case of symptomatic or central embolism, the suggested recommendation consists of initiating anticoagulation treatment with heparin followed by Coumadin for 6 months [91].

Neurologic Complications

Catastrophic neurologic injuries, including complete paraplegia, have been reported after intracanal cement leakage. In the majority of cases, this event is well tolerated. Neurologic damage is attributed to both exothermal injury to neural structures and neurocompression [103]. Not all cement extravasation into the epidural space is associated with complication [2,84]. Patel et. al reported a series of 10 patients with neurologic injury after kyphoplasty. Patients developed neurologic deficit either acutely (<24h) or gradually with an average of 37.1 days (range 3–112 days) postoperative. Most of these patients required revision open surgical intervention for treatment of their neurologic injury [104]. Epidural cement leakages may occur along 1 of the following pathways: the fracture line extending to the posterior wall of the vertebral body, the basivertebral foramina, the anterior internal venous plexus, or the needle tract. Cement viscosity is an important factor. Bone cement in a liquid low-viscosity state may extravasate rapidly into the spinal canal [103], particularly when injected under high pressure. Pedicle perforation or fracture during the procedure or posterior wall violation is considered a significant risk factor for intracanal cement leakage and neurologic complication [105]. Often epidural cement extravasation is subclinical and goes undetected unless a postoperative CT scan is performed [103].

Intraforaminal leakage can be associated with radiculopathy. Occasionally patients with neuroforaminal extravasation require surgical decompression. However, in most cases, the symptoms respond well to conservative treatment or local steroid injection [106]. Transient femoral neuropathy has also been reported after cement leak into paravertebral muscles [17].

Neurologic complications associated with cement leakage in kyphoplasty are avoided if the posterior vertebral body wall and the pedicles remain intact, along with using continuous biplane fluoroscopy and preservation of the medial pedicle wall [107,108].

Adjacent Fracture

There is controversy regarding the risk of a subsequent fracture with vertebral augmentation. Some authors suggest that the alteration of biomechanical balance caused by the cement filling can lead to a stress-shielding phenomenon on the adjacent vertebral bodies [109]. Others advocate that the strengthening of the vertebral body with cement and the correction of the kyphosis achieved by kyphoplasty prevent a secondary fracture [110]. The mechanism for adjacent vertebral fracture is not clear, but it is speculated that the increased stiffness of the augmented vertebra changes the biomechanics of load transfer to the adjacent vertebrae. Although it is difficult to determine the optimal amount of cement filling, it is possible that rigid augmentation may also provoke failure of the adjacent, non-augmented level [111]. Lin et al. showed that more than 70% of patients who sustained a subsequent fracture after vertebroplasty had intradiscal cement leak. Cement extravasation into the disc may increase the risk of a secondary fracture due to alteration of disc flexibility [112]. Also, patients with predominantly lower bone density, larger balloon or cement volume, fissure fracture, steroid use, and absence of systemic antiosteoporosis therapy have an increased risk of contiguous vertebral compression fracture [113-115].

Many authors argue that adjacent fractures have also been reported in untreated patients suggesting that this is a result of the preexisting osteoporosis rather than the procedure itself [116]. Additionally, kyphotic deformity caused by untreated OVCFs is another predisposing factor for secondary fracture development as it transfers the center of gravity forward resulting in an increased forward-bending moment which subsequently enhances the load within the kyphotic angle. Therefore kyphosis reduction due to kyphoplasty is expected to lessen the risk of new fracture development [117] (Figures 6 and 7).

In a 1-year follow-up study, kyphoplasty as an addition to medical treatment and when performed in appropriately selected, patients showed improvement in the

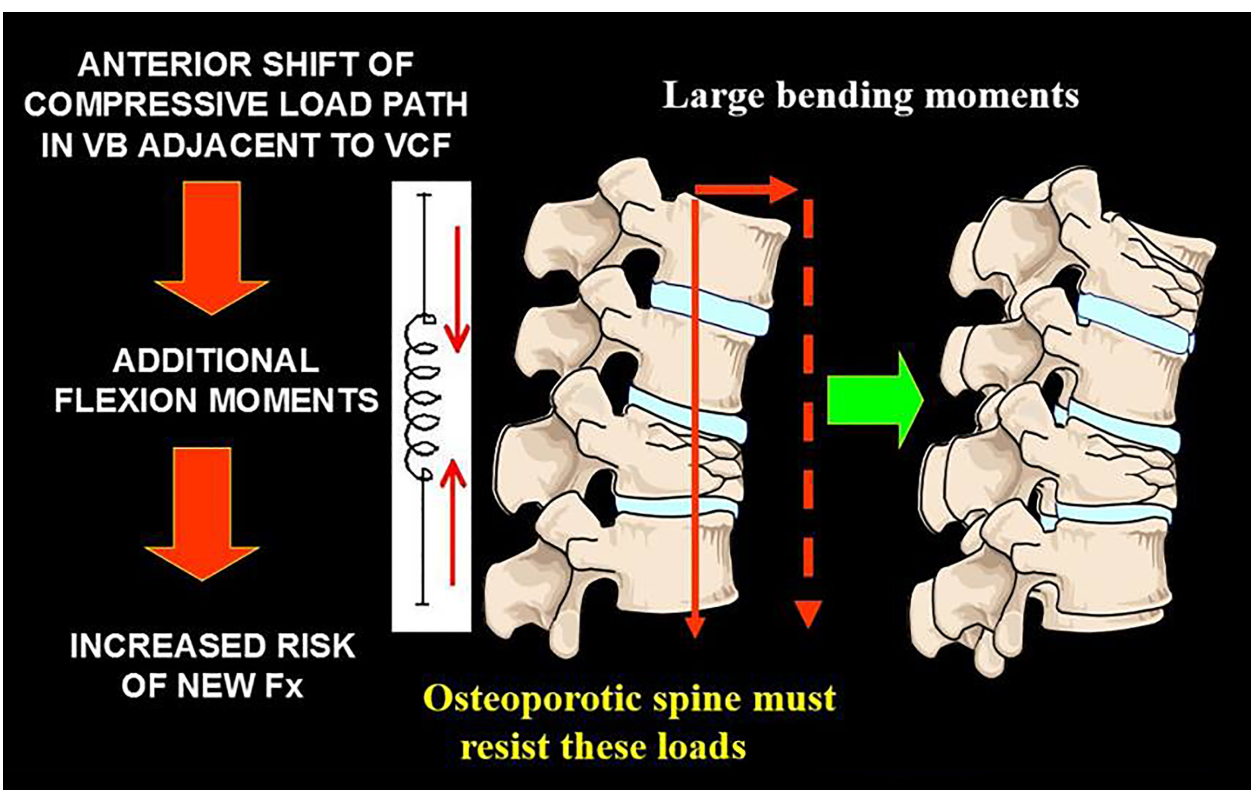

Figure 6. The mechanisms of kyphosis development in the osteoprotic spine.

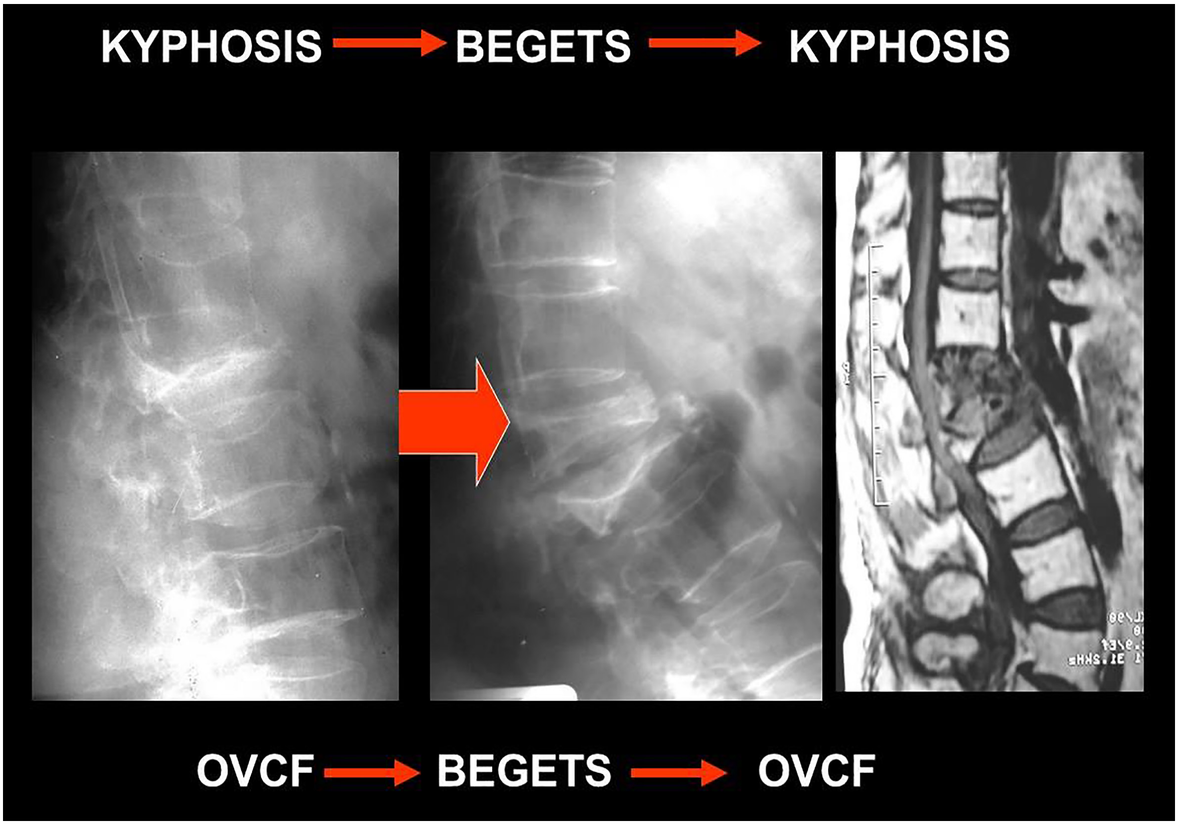

Figure 7. Kyphosis begets kyphosis and OVCF begets OVCF.

occurrence of new vertebral fracture in individuals with primary osteoporosis [33]. Similarly, after 3 years in a prospective study, the incidence of new vertebral fractures after kyphoplasty was significantly reduced versus control. All patients received pharmacological antiosteoporotic treatment, analgesics, and physiotherapy. Pain and function were also improved in the study group [35]. A recent meta-analysis of 12 studies involving 1,328 patients (768 who underwent augmentation procedure with PMMA and 560 who received nonoperative treatment) revealed that the risk of adjacent vertebral body fracture was equivalent between cementoplasty (vertebroplasty and balloon kyphoplasty) and conservative treatment [118].

Rib Fractures

Rib and sternum fractures are an infrequent complication. A systematic review cited 8 studies that reported incidence ranges from 0.6%–4.3% [81]. Improper patient positioning as well as leaning over the patient's back during surgery may result in rib fractures [17,103,119]. We experienced a case in which a patient with a successful kyphoplasty procedure who was seriously compromised with severe pain from 4 rib fractures. This complication occurred when pressure was applied over the kyphotic deformity in order to reduce the wedged vertebra.

Infection

Postoperative infection is a rare but devastating complication of kyphoplasty. A few cases have been reported in the literature [120,121]. Ongoing back pain and/or neurologic complication are the predominant presenting symptoms. Staphylococcus aureus is the most common pathogen [122,123]. Tuberculous spondylitis has also been reported [124]. Several studies have claimed that infection after cementoplasty procedure is likely related to a prior systemic infection, an immunocompromised condition, or intraoperative contamination. Preoperative prophylactic antibiotic administration is recommended. Cement mixed with antibiotics has also been recommended in the cases with a previous infection or in immunocompromised patients [125]. In case of concurrent infection, the procedure must be postponed until the infection is controlled. Cementoplasty infection can be treated conservatively with a course of antibiotics based on antibiotic sensitivity testing [126]. Infection refractory to conservative treatment or recurrent infection should be treated with corpectomy, cement removal, and instrumented spinal reconstruction [125].

Radiation Exposure

Long-term low-dose radiation exposure has been associated with leukemia, and thyroid or other cancers [127]. Nonneoplastic effects of radiation include genetic mutation, cataract, and developmental malformation of the fetus [127]. Radiation exposure and associated risks during cement augmentation procedures may be considerable for the patient, the surgeon and the staff; and therefore, actions should be taken to minimize exposure [128]. Mroz et al. reported that during kyphoplasty, the exposure time was 5.7±2.0 minutes/vertebra for a 1-level, 3.9±0.8 minutes/vertebra for a 2-level, and 2.9±1.2 minutes/vertebra for a 3-level kyphoplasty. Surgeon exposure as measured by the protected dosimeter was less than the minimum reportable dose (<0.010 mSv). Exposure as measured by the unprotected dosimeter, which is equivalent to deep whole-body exposure, was 0.248±0.170 mSv/vertebra. Eye exposure was 0.271±0.200 mSv/vertebra, and the shallow exposure (hand/skin) was 0.273±0.200 mSv/vertebra. Hand exposure was 1.744±1.173 mSv/vertebra. Without eye or hand protection, total radiation exposure dose to these areas would exceed the occupational exposure limit after 300 cases per year [129]. Protection of the hands and the eyes of the surgeon by using proper safety equipment, including radiation safety gowns, thyroid shields, gloves, and lead glasses, is strongly recommended [130]. In a similar study, emphasis was given to the importance of surgeons wearing lead glove protection on their leading hands during percutaneous vertebroplasty procedures. This measure has resulted to a 75% reduction rate of exposure to radiation [131].

Measures to minimize radiation exposure during kyphoplasty involve the use of low-dose or pulsed fluoroscopy [132] and the use of simultaneous biplanar fluoroscopy. When an optimal setting has been found, it is continued throughout the procedure and radiation is not "wasted" readjusting to a second plane of view [133]. Patient and staff radiation exposure is closely associated with their distance from the fluoroscopy beam. The source-to-skin distance during the procedure should not be less than 35 cm [134]. Unprotected staff working less than 70 cm from a fluoroscopic beam receive significant amounts of radiation, whereas those working more than 91.4 cm from the beam receive an extremely low amount of radiation [135].

Cost

Cost effectiveness is a contentious issue. The cost effectiveness of vertebral augmentation techniques for OVCFs has been challenged [136,137]. A drawback of balloon kyphoplasty is the high cost of the instrumentation which has been estimated at 3,500 euro per treated level, whereas for vertebroplasty the cost is approximately 500 euro per level [138,139]. There is an additional cost and risk of general anesthesia with kyphoplasty, although it can be performed using local anesthesia for 1 or 2 levels. Multiple levels are often under general anesthesia. Studies have not taken into consideration patients with neurologic and musculoskeletal problems associated with OVCFs. Osteoporotic compression fractures have been associated with a 15% higher mortality rate [140,141]. Even for the oldest patients, both procedures are considered to be cost effective in terms of cost per life-year gained [142]. Patients have been found to require primary care services at a rate 14 times greater than the general population in the first year after a symptomatic vertebral fracture [143]. Compared to conservative treatment, significant reduction in mortality and drift in social functionality in patients treated with balloon kyphoplasty was identified at 1-year follow-up in a prospective UK study [144]. A cost-effectiveness analysis of OVCFs treatment among 858,978 patients in the Medicare dataset (2005–2008) demonstrated kyphoplasty as cost effective and cost saving compared with vertebroplasty [142]. Borse conducted a cost-utility analysis from a payer's perspective using a Markov model to assess the cost utility of balloon kyphoplasty compared with vertebroplasty. They found that balloon kyphoplasty is associated with better utility and higher effectiveness compared with vertebroplasty [145].

CONCLUSIONS

Based on the best available evidence in our review of the literature, it appears that both vertebroplasty and kyphoplasty are valuable procedures in the management of OVCFs. These minimally invasive surgical procedures are not without risk, but potential complications can be minimized. It is imperative to take caution and care with these procedures and identify and promote best practice. In a systematic review [17] analyzing several reports on OVCFs it appears that osteoporosis is not innocuous as it can be complicated with serious neurological deficit and pulmonary and social problems. One third of these patients develop variable degrees of back pain attributed to facet arthropathy, deformity, and pseudoarthrosis. In a recently published book "Ending Medical Reversals", the authors extensively criticized vertebroplasty as ineffective and a harmful medical practice [146]. The majority of studies we reviewed support cementoplasty. A recent RCT [19] exonerates vertebroplasty by demonstrating its superiority over sham procedure and the potentially serious complications of OVCFs [17].

Vertebroplasty is indicated for the uncomplicated OVCF in the first 3 months and appears a more cost-effective procedure. In the early post-fracture period, some reduction of the fracture with postural hyperextension can be accomplished. To minimize cement extravasation, the cement should be of higher viscosity and should be inserted slowly using the kyphoplasty cement bone fillers. Balloon kyphoplasty is indicated in older fractures, when postural reduction is not feasible, and in established pseudoarthrosis. In cases of indeterminate cement interdigitation which may not prevent anterior cement migration and loss of reduction, this procedure can be augmented by a short posterior transpedicular stabilization.

We believe that a well designed randomized controlled trial which includes stratification of patient morbidity, metabolic bone activity, and vertebral fracture activity is needed at this point. Patients with OVCFs are likely to have comorbid conditions and the indication for intervention, optimal timing, and manner of cementoplasty is still indeterminate.

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