Osteoporotic Vertebral Compression Fractures: A Review of Current Surgical Management Techniques

Michael Shen, MD, and Yong Kim, MD

Abstract

Of the estimated 1.5 million osteoporosis-related fragility fractures that occur each year in the United States, vertebral compression fractures (VCFs) are the most common. It is estimated that approximately 20% to 25% of people who sustain a VCF have symptoms severe enough to seek medical attention. However, nonoperative outpatient management for VCFs is often successful in only 75% to 80% of cases. In this article, we provide a comprehensive review of VCFs and of the surgical alternatives for VCF management, including indications for surgical intervention, overview of surgical techniques, clinical results, complications, and areas of future investigation.

Bone production and bone degradation occur in a delicate homeostatic state. Shifting this balance toward one state or the other favors either creation of new bone or breakdown of bone that has already formed. Disorders in which this balance is thrown off can be categorized as quantitative (changes in size or amount of normal bone) or qualitative (changes in properties of normal bone). Osteoporosis is a quantitative bone disorder.

Osteoporosis

Definitions and Epidemiology

As defined by the National Osteoporosis Foundation, osteoporosis is a disease characterized by low bone mass and structural deterioration of bone tissue, leading to bone fragility and increased susceptibility to fractures. The World Health Organization defines osteoporosis by comparing a person's bone mineral density (BMD) with that of the mean of a young reference population. People can then be categorized as having low bone mass, osteoporosis, or severe osteoporosis. The osteoporosis diagnosis can then be further classified as primary or secondary, depending on the underlying etiology (Table I).

Population studies have estimated that approximately 10 million people in the United States have osteoporosis, while another 34 million carry the diagnosis of having low bone mass. Osteoporosis tends to affect women 4 times more than men and is found more predominantly in Caucasians and people of Asian descent. The lifetime incidence of fragility fractures secondary to osteoporosis in people older than 50 is about 1 in 2 for women and 1 in 4 for men.

Fragility fractures secondary to osteoporosis place a major financial burden on the health care industry. As estimated, there were approximately 1.5 million osteoporosis-related fractures in the United States in 2001. Care for these fractures cost about $17 billion, or approximately $47 million a day. As the older-than-50 population continues to grow, costs will almost quadruple to an estimated $60 billion a year by the year 2030—a record $164 million a day.[1]

> "...there were approximately 1.5 million osteoporosis-related fractures in the United States in 2001."

Diagnostic Imaging Modalities

Multiple imaging modalities can be used to evaluate BMD and diagnose osteoporosis. Radiography, ultrasound, and computed tomography (CT) can be used to measure BMD centrally (ie, spine, hip, femur) and peripherally (ie, hand, foot). The gold standard of these modalities is dual-energy x-ray absorptiometry (DEXA). DEXA is the most commonly used and most easily reproducible BMD measurement technology, and it has the highest sensitivity and specificity.

Dr. Shen is Orthopaedic Surgery Resident, and Dr. Kim is Clinical Assistant Professor, Department of Orthopaedic Surgery, New York University/Hospital for Joint Diseases, New York, New York.

Requests for reprints: Michael Shen, MD, Department of Orthopaedic Surgery, New York University/Hospital for Joint Diseases, 301 E 17th St, New York, NY 10003 (phone, 212-598-6000; fax, 212-598-6581; e-mail, drmichaelshen527@yahoo.com).

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Table I. Osteoporosis Classification

Normal	Bone mineral density within 1 SD of the mean of a young adult reference population
Osteopenia	-1.0 to -2.5 SDs below
Osteoporosis	<-2.5 SDs below
Severe osteoporosis	Osteoporosis with ≥1 fragility fracture
Osteoporosis classification	
• Primary	
Type 1	Postmenopausal/estrogen-deficient
Type 2	Age-related/senile
• Secondary	

Table II. Osteoporosis Risk Factors

Female
Caucasian/Asian
History of fracture in a first-degree relative
Thin and/or small frame
Advanced age
Family history
Estrogen deficiency
Amenorrhea
- Anorexia/bulimia
- Excessive physical exercise

Low lifetime calcium/vitamin D intake/deficiency
Inactive lifestyle
Smoking
Excessive alcohol intake
Medications
- Corticosteroids
- Excessive thyroid hormones
- Anticonvulsants
- Aluminum-containing antacids
- Methotrexate
- Gonadotropin-releasing hormones
- Cyclosporine A

Low testosterone levels (men)

Risk Factors

Many factors can put a person at risk for development of osteoporosis (Table II). Primary osteoporosis can be divided into type 1 and type 2. Type 1 osteoporosis, or osteoporosis due to menopause or estrogen deficiency, is found more in Caucasian women and women of Asian descent. Increased age puts people at risk for developing type 2 osteoporosis, also known as *senile osteoporosis*. As with many disease states, heredity may increase a person's susceptibility to fracture. Family history of low bone mass or having a primary relative with a fragility fracture can increase risk for developing osteoporosis. Early menopause—brought about naturally, or by surgery or amenorrhea caused by conditions such as eating disorders or excessive physical exercise—also increases the risk. Chronic diseases, or medications used to treat these diseases, may have side effects that can damage bone or interfere with bone formation leading to osteoporosis. Last, certain lifestyle choices—including poor diet, smoking, excessive alcohol intake, or lack of weight-bearing exercise—can also increase the risk. By minimizing these modifiable risk factors, however, people at high risk for developing osteoporosis may be able to achieve higher peak bone mass in the hope of delaying or preventing the onset of osteoporosis.

Medical Treatment

Despite attempts to minimize risk factors, medical treatment for osteoporosis is sometimes necessary. Estrogen, bisphosphonates, and calcitonin remain the most widely prescribed medications for osteoporosis treatment.[2] Other medications that may be used include raloxifene (an estrogen receptor modulator used in people at high risk for developing breast or endometrial cancer) and teriparatide (a human parathyroid hormone derivative). Medical treatment for osteoporosis has been shown to decrease the incidence of vertebral fractures by 40% to 60% after just 1 year of treatment. However, despite the efficacy of medical treatment for osteoporosis, only 50% of women with vertebral compression fractures (VCFs) diagnosed incidentally with chest radiographs are started on any pharmacologic treatment for their underlying disorder.[2]

Vertebral Compression Fractures

Epidemiology

Of the estimated 1.5 million osteoporosis-related fragility fractures occurring annually in the United States, VCFs are the most common, accounting for approximately 700,000 injuries. Overall VCF incidence in women older than 50 is estimated to be approximately 17.8/1000 person-years. After age adjustments are made, incidence can be seen to increase with aging: the incidence of 5.8/1000 person-years in 50- to 54-year-old women increases to 26.1/1000 person-years in 75- to 79-year-old women.[3] In their study of nearly 2700 women (mean age, 74 years), Lindsay and colleagues[4] found the relative incidence of VCFs to be 6.6% after 1 year, rising to 19% the year after a VCF. Ross and colleagues[5] found the risk for subsequent fracture to increase 5-fold after initial VCF and 12-fold after 2 or more VCFs. Other studies focusing on BMD have shown the relative risk for developing a fracture to increase almost 4 to 6 times with a 2-SD decrease in BMD.[6,7] However, neither low BMD nor previous VCF has been shown to predict which people will sustain a new VCF.

Presentation

Approximately 20% to 25% of people who sustain a VCF develop symptoms severe enough to seek medical attention.[4] Patients can present with complaints of varying degree (Table III), the most common complaint being pain. History often shows that pain usually begins

Table III. Patient Presentation With Vertebral Compression Fractures

Severe back pain after minor injury
Pain worse by standing erect
Pain usually limits ambulation
• Wheelchair
• Stooped forward
Deep pressure over spinous process at involved level reproduces pain
Kyphotic deformity and postural changes
• Changes in balance
• Knees bend, hips flex, and pelvis tilts to offset center of gravity moving forward
• Increased muscle fatigue
Protuberant abdomen
Urinary retention
Gastrointestinal symptoms (ileus)
Decreased gait velocity
Psychosocial issues because of appearance
Neurologic deficits rare

after only minor injury. The pain may be reproducible on examination with deep pressure over the spinous process of the involved level. Pain tends to be postural, made worse by standing erect, and can be debilitating to the point of confining a person to a wheelchair or bed. Deformity due to VCF can cause both visual changes (kyphosis, protuberant abdomen) and psychosocial changes (depression). Increased kyphosis due to VCF has been found to be associated with decreased truncal strength and pulmonary function.[8,9] Patients with VCFs are 2 to 3 times more likely to die secondary to pulmonary causes like chronic obstructive pulmonary disease or pneumonia, and overall they have a slightly increased relative risk for hospitalization and mortality.[10,11] Urinary retention and gastrointestinal symptoms are also common manifestations in people with VCFs.

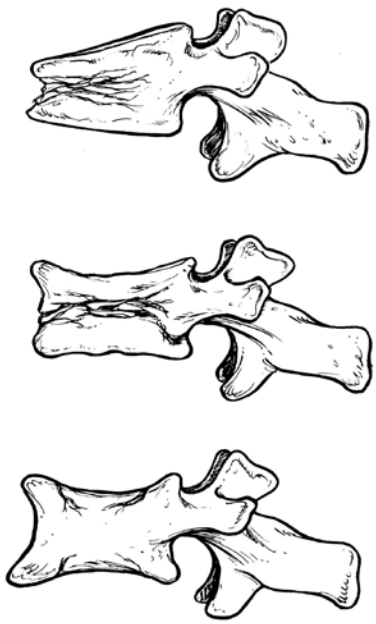

Figure 1. Classification of vertebral compression fractures. Top to bottom: wedge, crush, biconcare. Artist: Hugh Nachamie.

Neurologic deficits can also occur, but these symptoms usually resolve, and less than 5% of patients will go on to require surgical decompression.[12]

Classification and Evaluation

VCFs are commonly classified simply according to their morphologic appearance: wedge, crush, or biconcave (Figure 1). Wedge and crush fractures occur predominantly in the midthoracic and thoracolumbar regions, while biconcave fractures occur more often in the lumbar region. Crush fractures are associated with the greatest loss of vertebral height (vertebra plana is the extreme). In a large study, Ismail and colleagues[13] found that the number of wedge fractures far surpassed that of the other fracture types—accounting for more than 50% of all the VCFs they studied. Biconcave fractures accounted for 17%, crush fractures for 13%, and various combinations of the 3 fracture types for the rest.

Predicting degrees of pain and dysfunction based on radiologic imaging has proved controversial. Ismail and colleagues[13] were unable to demonstrate any correlation between fracture type and degree of collapse with patient age, sex, or level of pain. However, Lyritis and colleagues[14] identified 2 types of patients and categorized them into groups based on fracture pattern. One group presented with obvious fractures that did not change over time and that were accompanied with acute-onset, severe, sharp pain that gradually improved over 4 to 8 weeks; pain management and early mobilization were emphasized for these patients. The other group presented with minimal radiologic changes, developed subsequent collapse and debilitation over time, and had dull, less severe pain that recurred over 6 to 18 months; long-term management (hormone replacement, dietary supplementation) and bracing were used to prevent further collapse.

Histologically, osteoporosis causes trabecular atrophy and increased spacing between trabeculae—particularly evident in the anterosuperior portion of the vertebral body.[15] The anterosuperior defect renders this area weaker and more susceptible to trauma than other regions of the vertebral body. Many elderly people also have some degenerative disc disease, a condition that causes normal intradiscal pressure to shift and concentrate load to the peripheral aspects of the vertebral body.[16] That these disorders commonly occur together in elderly patients to some degree might help explain the increased prevalence of wedge fractures over all others.

Choice of Imaging Study. Various imaging studies can be done to evaluate VCFs. Radiographs remain the mainstay of diagnosis. Many VCFs are detected incidentally on chest radiographs. Once a VCF is diagnosed, additional imaging can be done to further evaluate the injury, if indicated. CT scans are excellent for delineating bony anatomy. Bone scans are very sensitive but can remain positive for up to 2 years after injury, therefore making it a poor test for establishing chronicity. Magnetic resonance imaging (MRI) can provide a great deal of information. Although not as good as CT in evaluating bony anatomy, MRI is helpful in evaluating the surrounding soft tissues and determining the chronicity of the injury as well as the underlying diagnosis (osteoporosis vs pathologic lesion).

"Outpatient management is unsuccessful in approximately 15% to 20% of people who seek medical attention after VCFs."

Nonoperative Treatment Modalities

A majority of people with VCFs do not seek medical assistance after injury. For those who do, often the chief complaint is pain. Generally, patients who do not require bed rest can control their symptoms with activity modification, bracing, or assistive devices used in conjunction with narcotic analgesics. After patients are comfortably mobilized, a regimen of physical therapy can be started to further rehabilitation. For pathologic lesions, particularly radiosensitive tumors (breast, prostate, myeloma), radiotherapy has been found to provide pain relief in up to 50% of patients.[17] Several medications (eg, teriparatide, calcitonin) have not only been found efficacious in treating pain but carry the added benefit of treating the underlying osteoporosis.[18,19] Outpatient management is unsuccessful in approximately 15% to 20% of people who seek medical attention after VCFs. These patients usually require hospital admission for bed rest and intravenous analgesics. Bed rest in the elderly, however, is associated with progressive deconditioning. Elderly patients are at increased risk for developing pulmonary complications (pneumonia), decubiti, deep vein thrombosis, and urinary tract infections. Additionally, BMD has been found to decrease 0.25% to 1% per week of bed rest.[20,21] For elderly patients, who often are also osteoporotic, long-term bed rest can rapidly increase their risk for suffering not only additional VCFs but also other fragility fractures.

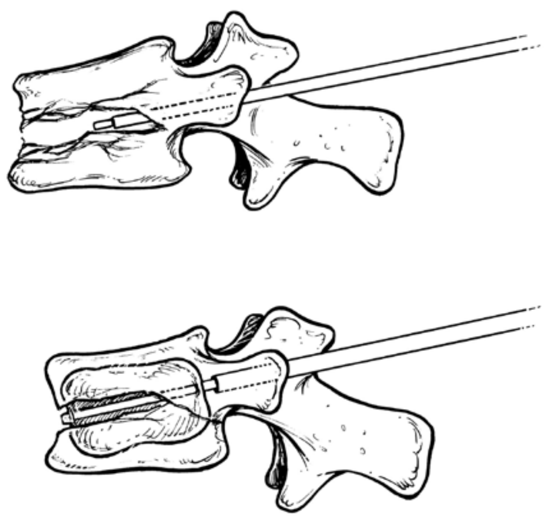

Figure 2. Vertebroplasty (top) and kyphoplasty (bottom). Artist: Hugh Nachamie.

Operative Treatment Modalities

Several operative treatment modalities may be used after nonoperative intervention fails. Indications for operative intervention include intractable pain, progressive neurologic deficit, and instability. Current operative techniques for treating VCF include decompression and fusion (anterior and/or posterior), vertebroplasty (VP), and kyphoplasty (KP).

Decompression and Fusion (Anterior and/or Posterior)

Fewer than 5% of people who seek medical treatment after a VCF require operative decompression and fusion. Surgical intervention for osteoporosis poses many challenges. Because of poor bone quality, hardware purchase is poor, and wire cutout is increased. Cases are often more extensile, thereby increasing operative time, anesthesia time, and the likelihood that transfusion will be needed. Last, elderly patients who are nursing-home bound or institutionalized are often nutritionally depleted, increasing their mortality rate and decreasing their healing potential postoperatively.[22]

Several techniques have been used to optimize results in patients with osteoporosis. Multiple segmental points of fixation are possible with longer constructs. Because the laminae of the vertebral body are composed of denser cortical bone, use of sublaminar wires to supplement fixation allows for creation of stronger constructs. Pedicle screw size can be increased and, when needed, augmented with polymethylmethacrylate (PMMA) or bone graft.[23,24] Incorporating these strategies in patients with osteoporosis can lead to stronger operative constructs and better surgical results.

Vertebroplasty and Kyphoplasty

Techniques and Indications. VP was first used by Galibert[25] in 1987 for the treatment of painful vertebral hemangiomas (Figure 2). KP was introduced in 1998 to treat painful osteoporotic VCFs (Figure 2). Both procedures are minimally invasive and involve percutaneous injection of cement into the collapsed vertebral body. The differences between VP and KP are expanded on later in this article.

Current indications for VP and KP are in patients with intractable pain who sustain VCF secondary to osteoporosis, multiple myeloma, or other osteolytic metastatic lesions. Contraindications include use in young patients, pregnant women, and patients with high-energy injuries, local spine infections, or bleeding disorders.

Fracture Reduction. One difference between VP and KP involves how the vertebral body is prepared before cementing. Fracture reduction is achieved during VP by a combination of outward pressure exerted by the cement during injection and patient positioning. In static fractures (fractures without an observable and mobile radiolucent intravertebral cleft), the mean increase in anterior height after VP is 2.5 mm.[26] With mobile fractures and patient positioning, up to 40% to 70% of normal anterior height is sometimes restorable.[27]

KP utilizes an inflatable balloon tamp to create a cavity within the vertebral body for cement placement. The balloon tamp also assists in fracture reduction, improving both kyphosis and vertebral body height. Overall, height restoration is often improved by 50% to 70% postoperatively, and segmental kyphosis by 6° to 10°.[28-31] However, when injury chronicity is taken into account (acute is <10 weeks from time of injury; chronic is >4 months), improved fracture height restoration, kyphosis reduction, and pain relief occur after treating acute fractures versus chronic ones.[32]

Clinical Results. Short-term results for VP and KP are encouraging. A literature review of patient results shows that 75% to 100% and 85% to 100% of people with osteoporotic VCFs have good to moderate pain relief after VP (Table IV) and KP (Table V), respectively.[28,31-47] In all the studies, many of the patients reported pain relief almost immediately after surgery and were able to be mobilized within 24 hours postoperatively. Pain relief for patients undergoing VP secondary to pathologic lesions seems more variable than pain relief after similar treatment with KP (good to moderate pain relief in 50%-90% of patients after VP and in 80%-90% after KP). Not only is substantial pain relief obtained over the short term, but long-term VP studies are showing that pain relief is maintained even 4 to 5 years after surgery.[39,44] Because KP is a newer technique, long-term results on patient satisfaction and pain relief are still pending.

Patient factors such as age, gender, baseline BMD, history of tobacco or steroid use, and presence or absence of dynamic mobility within the fracture all have been found to have no influence on degree of postoperative pain relief.[43] However, Alvarez and colleagues[48] identified patients with an American Society of Anesthesiologists score of 1, symptomatic VCF levels confirmed by MRI, and vertebral body height loss of less than 70% to have improved and more predictable postoperative pain relief.

Complications. No procedure is without its complications, however infrequent.

Table IV. Vertebroplasty Results

Study	Patients (N)	Levels Injected (N)	% Pain Relief: Good to Moderate	% Pain Relief: Poor	Follow-Up (mo)	Subsequent Fractures (N)
Barr et al[33]	38	70	95	5	18	5
Cyteval et al[36]	20	23	90	10	6	5
Cortet et al[35]	16	20	100	0	6	0
Perez-Higueras et al[44]	13	27	100	0	60	4
Grados et al[39]	25	34	96	4	48	34
Heini et al[40]	17	45	76	24	12	2
Zoarski et al[47]	30	54	96	4	15	0
Kobayashi et al[41]	196	250	96	4	15	37
Fourney et al[37]	33	65	90	10	4.5	—
McKiernan et al[43]	46	66	100	0	6	4

Table V. Kyphoplasty Results*

Study	Patients (N)	Levels Injected (N)	% Pain Relief: Good to Moderate	% Pain Relief: Poor	Follow-Up (mo)	Subsequent Fractures (N)
Berlemann et al[34]	24	27	96	4	12	1
Wilhelm et al[46]	34	56	100	0	12	—
Phillips et al[31]	29	61	86	14	12	5
Crandall et al[32]	47	86	90 (A), 87 (C)	10 (A), 13 (C)	18	—
Gaitanis et al[28]	32	61	97	3	12	2
Fribourg et al[38]	38	47	—	—	8	17
Lane et al[42]	19	46	83	17	3	—
Fourney et al[37]	13	32	91	9	4.5	—
Rhyne et al[45]	52	82	VAS 9.16 –> 2.91 (0-10)	—	9	7 (patients)

*VAS indicates visual analog scale; A, acute; C, chronic.

Table VI. Vertebroplasty and Kyphoplasty Complications

Transient
- Radiculopathy
- Local pain
- Fever

Fat emboli
Pedicle fracture
Balloon rupture
Infection
Rib fractures
Reaction to cement
Adjacent-level fracture
Pulmonary embolization
Cement extravasation/embolization
- Cement pulmonary emboli
- Nerve root compression/injury
- Spinal cord compression/injury
- Cerebral emboli

Cement Extravasation. One complication that can be encountered during VP and KP is cement extravasation. Extravasation can be due to cement overflow, outflow through cortical breeches, and improper placement.[49] Incidence of extravasation after VP ranges from 30% to 70%, while incidence after KP is less than 10%.[50] There are several reasons for the much lower incidence of extravasation after KP. First, the inflatable balloon utilized during KP tamps open a space within the vertebral body, forming a cavity surrounded by impacted cancellous bone. This compacted shell of bone serves as a barrier that helps prevent cement extravasation. Second, the volume of the cavity and thus the amount of cement to be used are easily determined by measuring the amount of fluid used to insufflate the balloon tamp—preventing overuse of cement and thus cement overflow. Third, while VP is a high-pressure system, the cavity formed during KP provides a low-pressure environment that allows cement with higher viscosity to be used with lower injection pressure, both of which decrease the risk for extravasation through cortical breeches.

The vertebral venous system provides another site for cement extravasation and embolization. Case reports of cement embolization to the lungs and even the brain have been reported in the literature. Histologic evaluation of VP- or KP-treated vertebrae within cadaver specimens has revealed cement particles within vascular spaces.[51] Groen and colleagues[52] performed a critical analysis on the vertebral venous system, identifying possible sites of cement extravasation and embolization. They proposed that increasing vertebral venous pressure intraoperatively could lessen the pressure differential between the injected cement and the venous system, and may even reverse it, thus lowering the risk for embolization. Increasing vertebral venous pressure can be accomplished through patient positioning and through anesthesiology in patients under general anesthesia. A more in-depth list of complications appears in Table VI.[53-60]

Adjacent-Level Fractures. Incidence of adjacent-level fractures after VP and KP varies from 12% to 50% and from 20% to 30%, respectively.[38,39,61-63] Most of these fractures occur within the first 2 to 3 months postoperatively.[38,63] Why they occur postoperatively has not been answered but is most likely multifactorial. Unlike earlier attempts to obtain maximum height restoration and vertebral body strength and stiffness, biomechanical studies have shown overly stiff vertebrae and attempts to obtain maximum height correction to be possible risk factors for adjacent-level fractures.[64] Complete fills are no longer encouraged, and attempts are now made to restore vertebral stiffness to preoperative levels.[65-67] Additionally, the fill volumes required to restore vertebral stiffness have been found to differ by cement brand.[68] Site of an initial VCF can also play a role in adjacent-level fractures. Adjacent-level fractures occur more often in the thoracolumbar region and less so in the thoracic and lumbar levels.[64] Leakage of cement into the disc space can also increase the risk for adjacent-level fractures.[69] Last, given the 20% natural incidence of a second VCF occurring within a year of the initial one, another major factor in the development of adjacent-level fractures may be the natural progression of osteoporosis within the surrounding vertebral bodies.

Future Directions. Alternatives to PMMA include calcium phosphate cement (CPC), hydroxyapatite, and coral granules. One advantage of using these alternative materials is that they produce less heat during polymerization, decreasing the likelihood of heat-induced thermal necrosis or damage to surrounding structures. Additionally, these alternatives may allow for bone ingrowth and subsequent replacement (this is a theoretical effect that has yet to be shown to occur in vivo in elderly people with osteoporotic bone). Disadvantages of these newer materials include high cost and difficulty of use because of their high viscosity.

Experience with these alternatives is growing, and preliminary results are encouraging. Biomechanically, no statistically significant difference has been found between PMMA and CPC in restoring both vertebral strength and stiffness.[70] In addition, postoperative pain relief and functional improvement profiles are similar in comparisons between PMMA and CPC.[71,72] However, these results are short-term only, and long-term follow-up studies are still pending.

Fracture Prophylaxis Using Reinforcement. Prophylactic reinforcement of osteoporotic vertebral bodies before injury is a concept that has just recently been introduced in the literature. Sun and colleagues[73] introduced a computer-generated biomechanical model to examine the effect of virtually implanted cement on compression strength in vertebrae of varying BMD before injury. In samples they designated "high fracture risk" (100% fracture risk in vertebral bodies able to sustain <1.6 MPa of stress), a 20% fill of PMMA improved mechanical integrity to “low fracture risk” (0% fracture risk, able to sustain >2.7 MPa of stress).

Discussion

Osteoporosis remains a major medical concern in the United States. If projections about future costs are correct, treatment of patients with fragility fractures secondary to osteoporosis could in itself almost bankrupt the health care industry. The best treatment for osteoporosis remains early intervention and medical management. Physicians who instill good lifestyle choices in patients early on (diet rich in calcium and vitamin D, no smoking, limited alcohol intake, regimen of weight-bearing exercise) and who aggressively medically treat patients who already have osteoporosis can save countless people from having to endure the pain and debilitation that are secondary to a fragility injury later in life.

Patients who undergo VP or KP (vs nonoperative treatment) experience improved pain relief, decreased time to functional recovery, decreased use of analgesic medication, and overall shorter hospital stay.[74] Individuals opposed to VP and KP state that long-term results for operative and nonoperative intervention often parallel each other. Although that may be true, relieving pain and mobilizing frailer, elderly patients almost immediately postoperatively are critical in preventing the complications and deterioration that would almost certainly otherwise occur, leaving those patients bed bound. Long-term results for KP and for CPC are pending, but preliminary results appear promising.

VP and KP also have the advantage of reducing segmental kyphosis, thus improving or even preventing some of the physical and emotional problems seen in people who have sustained a VCF. Both procedures are relatively safe, and the incidence of postoperative symptomatic complications remains low. Although prophylactic reinforcement of osteoporotic vertebral bodies remains an interesting concept, the inability to predict accurately which people at high risk will go on to develop a VCF makes this alternative impractical and financially impossible. With continued improvement through biomechanical study, further refinement of alternative materials, and advancement in clinical experience, VP and KP, when used properly under the correct surgical indications, provide an excellent method for improving patient morbidity and long-term outcome.

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This paper will be judged for the Resident Writer's Award.