

**DANIEL J. MAZANEC, MD**

Director, Spine Center, Department of Physical Medicine and Rehabilitation, The Cleveland Clinic

**ALEX MOMPOINT, MD**

Spine Center, Department of Physical Medicine and Rehabilitation, The Cleveland Clinic

**VINOD K. PODICHETTY, MD**

Coordinator, Research Studies, Spine Center, Department of Physical Medicine and Rehabilitation, The Cleveland Clinic

**AMARISH POTNIS, MD**

Telemark Physical Medicine, Greenville, Pa

# Vertebral compression fractures: Manage aggressively to prevent sequelae

## ABSTRACT

New drugs to treat osteoporosis, along with two new minimally invasive surgical procedures, are important options for preventing vertebral compression fractures and treating severe back pain and disability. However, the mainstay treatments remain cautious use of analgesics, limited bed rest, and physical rehabilitation.

## KEY POINTS

Although most vertebral compression fractures are asymptomatic, they are often painful and nearly always associated with a significant increase in mortality and functional and psychological impairment.

Magnetic resonance imaging can help determine whether a compression fracture is old or recent, and whether it is due to osteoporosis or malignancy.

Bracing is commonly used in the nonsurgical management of acute fractures. Spinal orthoses help control pain and promote healing by stabilizing the spine.

Two new minimally invasive surgical procedures may provide immediate pain relief and improve fracture-related spinal deformity. Further study is needed to define the indications for these procedures and to determine their long-term safety.

**R**ECENT ADVANCES IN PREVENTING and managing acute vertebral compression fractures offer clinicians an opportunity to reduce its devastating impact, even in the face of an expanding aging population.

*See related editorial, page 88*

Although management generally consists of analgesics, bracing, physical therapy, and treatment of the underlying cause of the fracture, two new minimally invasive surgical procedures may provide immediate pain relief and improve fracture-related spinal deformity.

## CLINICAL PRESENTATION

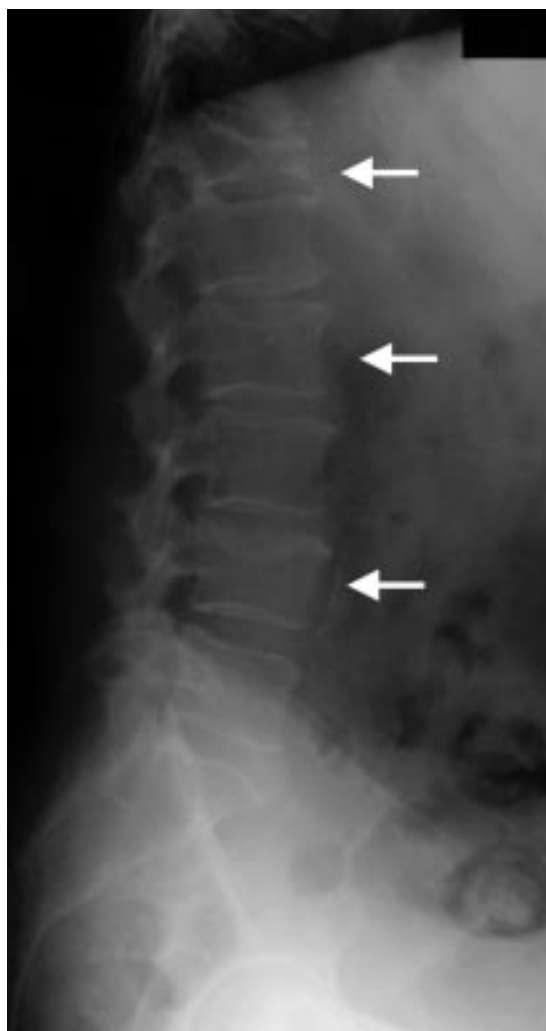
Vertebral compression fractures are common and serious. Each year, about 700,000 occur in the United States, with a prevalence of up to 25% in women over the age of 50.<sup>1-4</sup> Although only about a third are acutely symptomatic, nearly all are associated with a significant increase in mortality and functional and psychological impairment.<sup>5</sup>

A compression fracture is radiographically defined as a reduction in vertebral body height of more than 15%, typically seen on standing anteroposterior and lateral radiographs of the thoracolumbar spine (FIGURE 1).<sup>2</sup> The most common sites are in the thoracolumbar region, specifically T8, T12, L1, and the lower lumbar region (frequently L4).<sup>6</sup>

In most cases, patients do not recall any significant antecedent trauma, although they sometimes describe activities that increase the load on the vertebral column, such as raising a window, carrying a small child or a bag of groceries, or lifting in the forward flexed posture. High-energy trauma is more typically identi-

This paper discusses therapies that are not approved by the US Food and Drug Administration for the use under discussion.

**In an acute fracture, the patient is most comfortable when motionless**



**FIGURE 1.** Plain lateral radiograph of the lumbar spine depicts vertebral compression fractures at T12, L2, and L4 (arrows).

fied in younger patients, particularly men, with normal bone density.

Only about one third of vertebral compression fractures are symptomatic. If an acute fracture causes pain, it is usually felt deeply at the fracture site. Rarely, it may produce cord compression, presenting clinically with myelopathic features or with true radicular signs and symptoms.<sup>7–10</sup>

Since the pain of an acute fracture is aggravated by any movement, the patient is most comfortable when motionless. Physical examination may reveal tenderness to deep palpation or percussion over the affected vertebra, and paraspinal muscle spasm.<sup>2,6,11</sup>

The acute pain typically resolves after 4 to

12 weeks of limited activity. If the pain persists or gets worse after a period of relative improvement, this suggests additional compression or collapse.

In most patients, the acute incapacitating fracture pain subsides, but mechanical pain persists, due to altered spinal biomechanics and myofascial fatigue.<sup>2,12,13</sup>

### ■ CAUSES OF VERTEBRAL COMPRESSION FRACTURES

**Trauma** is the most common cause in patients under age 50, and because of this, fractures are actually more prevalent in men than in women up until age 60.

**Postmenopausal osteoporosis** is the most common cause after age 60.

**Malignancy.** Advancing age also increases the risk of pathologic fracture due to malignancy, and multiple myeloma, avascular necrosis, lymphoma, or other metastatic malignancies or infection must always be considered.<sup>14,15</sup> Vertebral compression fractures occur in 55% to 70% of patients with multiple myeloma and is the initial clinical sign in 34% to 64% of these patients.<sup>16,17</sup>

**Secondary osteoporosis.** Some patients are found to have bone density measurements well below age-expected values. In these cases, a secondary cause of bone loss should be considered, such as exogenous glucocorticosteroid therapy, excessive alcohol intake, hypogonadism, and endocrinopathies such as hyperthyroidism, Cushing disease, hyperparathyroidism, and diabetes mellitus.<sup>18</sup>

### ■ CONSEQUENCES OF VERTEBRAL COMPRESSION FRACTURES

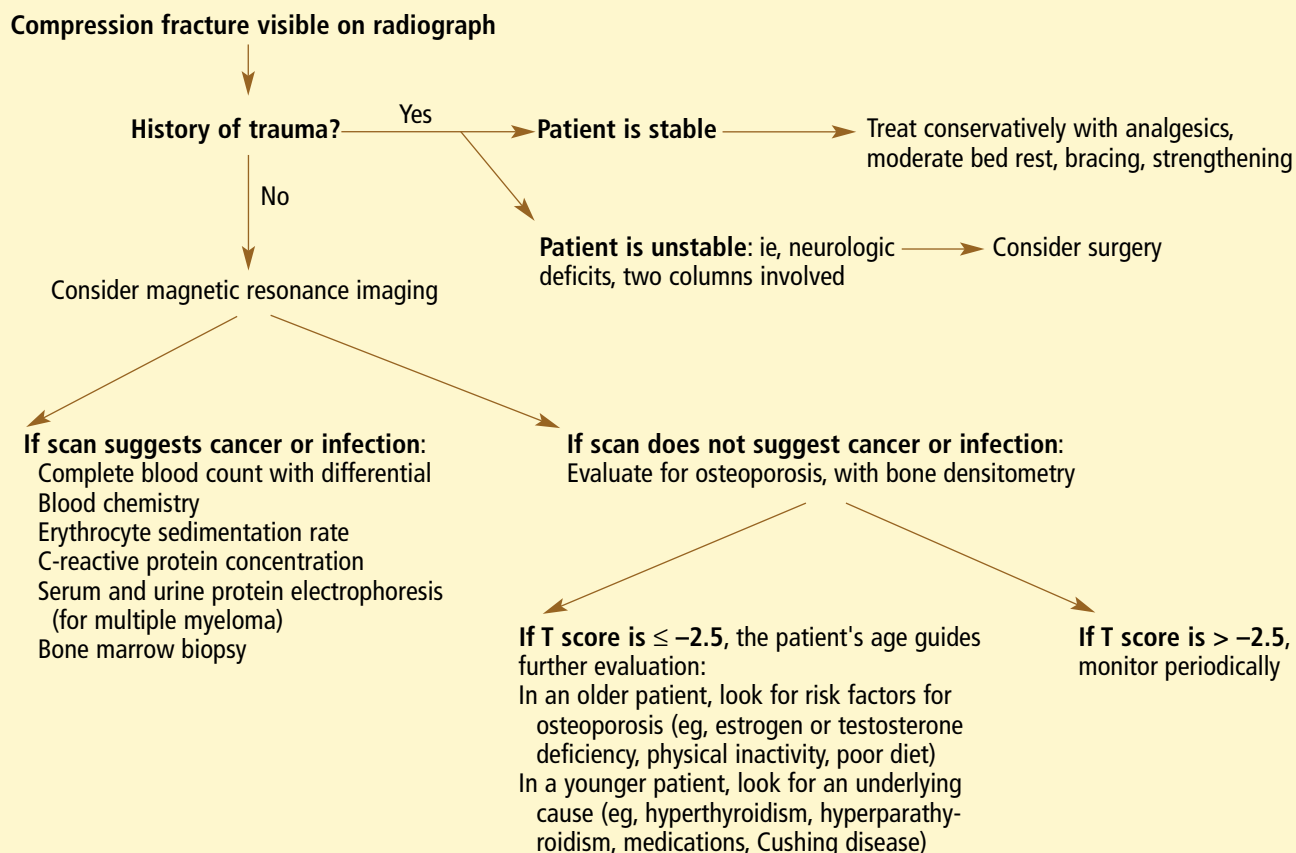
Whether compression fractures are acutely symptomatic or not, their long-term sequelae are significant. They can be categorized as biomechanical, functional, or psychosocial, although they are interdependent. Ultimately, compression fracture is associated with a significant decrease in survival.

#### **Biomechanical consequences**

**Persistent back pain** is due to mechanical factors and to muscle fatigue due to progressive spinal kyphosis.



## Suggested workup of a patient with a confirmed vertebral compression fracture



**FIGURE 2.** Suggested approach to diagnosis in patients with a new vertebral compression fracture

**Abdominal symptoms.** Progressive kyphosis, particularly with multiple compression fractures, shortens the thoracic spine and compresses the abdominal contents, which can lead to gastrointestinal symptoms such as early satiety and abdominal bloating. In some patients with significant thoracolumbar shortening, the lower ribs rest on the pelvic brim, producing lower abdominal discomfort. These abdominal symptoms may result in anorexia and subsequent weight loss, a particular concern in elderly patients who are already frail.<sup>2</sup>

**Pulmonary compromise** due to vertebral compression fracture and kyphosis typically consists of restrictive lung disease with reduced vital capacity. On the average, each

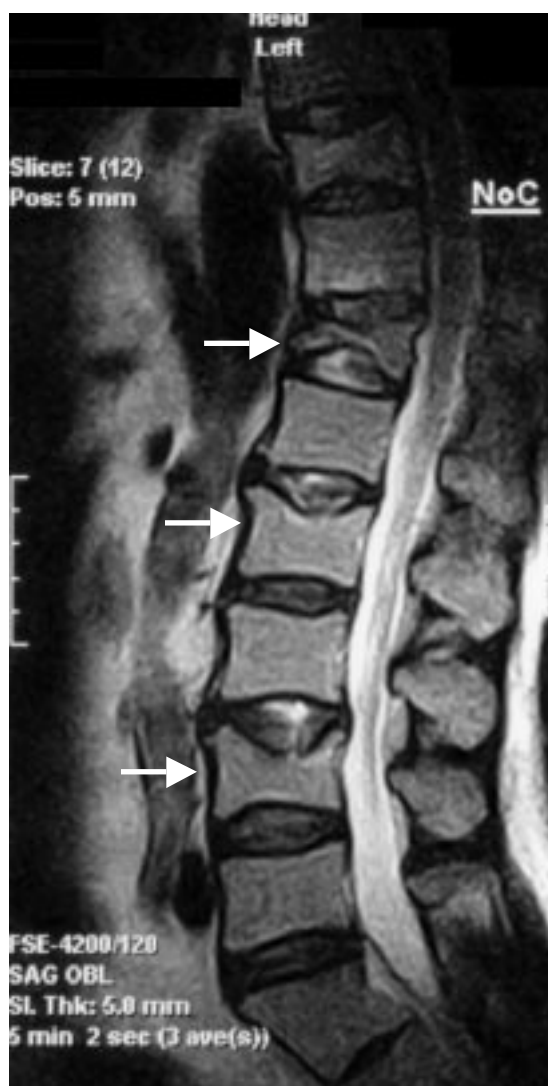
fracture reduces vital capacity by 9%.<sup>19,20</sup>

**Increased fracture risk.** As kyphosis develops, more force is transmitted to adjacent, already osteoporotic vertebrae, increasing the risk of additional fractures.<sup>21</sup> The presence of one or more vertebral compression fractures increases the risk of an additional fracture fivefold during the following year.<sup>2,22</sup>

### Functional consequences

Patients with compression fractures have lower levels of functional performance compared with controls,<sup>2,23</sup> need more assistance, experience more pain with activity, and have more difficulty with activities of daily living. A recent study<sup>24,25</sup> found that these patients

Up to 40%  
of patients with  
compression  
fractures  
develop  
depression



**FIGURE 3.** T2-weighted magnetic resonance image of the lumbar spine depicts compression fractures at T12, L2, and L4 (arrows).

had lower scores on a health-related quality of life index with respect to physical function, emotional status, clinical symptoms, and overall functional performance.<sup>24,25</sup> A fracture in the lumbar spine was most predictive of poor functional status.

Furthermore, many patients with multiple vertebral compression fractures become progressively inactive and sedentary, for a number of reasons, such as relief of mechanical pain in the supine position, fear of falling and additional fractures, and restrictive pulmonary disease. Inactivity, in turn, promotes decondi-

tioning, progressive deterioration in the ability to perform activities of daily living, and further bone loss.<sup>26</sup>

Pain and inactivity may disturb sleep patterns, promoting development of fibromyalgia-like myofascial pain.

### Psychological consequences

Depression develops in up to 40% of patients with compression fractures, due to chronic pain, changes in body image, deterioration in the ability to perform self-care, and prolonged bed rest. Patients more likely to develop depression have more than one fracture and tend to be older and more socially isolated.<sup>24</sup>

### Decreased survival

In a recent prospective cohort study of almost 10,000 women age 65 or older,<sup>24,27</sup> those with a compression fracture had a 23% higher rate of age-adjusted mortality. The rate was strikingly higher in women who had five or more of these fractures.

Vertebral compression fracture was related to an increased risk of pulmonary death, particularly in the presence of severe kyphosis. For unclear reasons, it was also associated with an increased risk of cancer death.<sup>27</sup>

### ■ IS TRAUMA THE CAUSE?

In general, once a vertebral compression fracture is observed on a plain film, the next step depends on whether the fracture is related to trauma (FIGURE 2). If trauma is the cause and the patient is stable, conservative management with analgesics, supportive care, and monitoring is appropriate. If the patient is not stable (eg, has a neurologic deficit on clinical examination or radiologic evidence of spinal fracture involving two columns), then surgery should be considered.

If no history of trauma is evident, magnetic resonance imaging (MRI) may identify malignancy or infection as the cause, in which case blood work, cultures, and bone biopsy may be in order. If MRI is normal, a workup for osteoporosis is recommended, with a focus on secondary osteoporosis in younger patients and primary osteoporosis in older patients.



## ■ IS THE FRACTURE OLD OR RECENT?

Although compression fractures are typically discovered on plain anteroposterior and lateral radiographs, these films do not provide information about the age of the fracture.

**MRI (FIGURE 3)** can help determine whether the fracture is old or recent, and whether it is due to osteoporosis or to malignancy, both of which may affect decision-making regarding treatment.

When evaluating the age of a compression fracture, T2 sagittal short inversion-time inversion-recovery (STIR) sequence MRI may be the most sensitive for assessing water content.<sup>28</sup> Acute fracture is identified by “bone edema.”

**Bone scanning**, especially single-photon emission computed tomography (SPECT) limited to the spine, may also help determine the acuity of the fracture.<sup>29</sup> In a retrospective study, Maynard et al<sup>30</sup> found that increased activity on a bone scan strongly predicted a positive clinical response (ie, relief of pain) to percutaneous vertebroplasty in osteoporotic vertebral compression fractures.<sup>30</sup>

## ■ OSTEOPOROSIS OR MALIGNANCY?

MRI also helps identify pathologic causes of vertebral compression fractures, such as malignancy.<sup>17,31,32</sup>

Baur et al<sup>31</sup> showed that in diffusion-weighted MRI scans, benign compression fractures have a negative bone marrow contrast ratio, whereas pathologic fractures have a positive ratio.

In another study, Rupp et al<sup>32</sup> concluded that signal changes on T1-weighted and T2-weighted MRI scans are not sufficiently specific to distinguish osteopenia from collapse due to metastasis, whereas pedicle involvement or an accompanying soft tissue mass was specific for a tumor-related vertebral fracture or lesion.<sup>32</sup>

In patients with multiple myeloma, the MRI scan may appear benign (band-like areas of low signal intensity underlying the fractured endplates), as in osteoporotic compression fractures.<sup>33</sup> Therefore, an apparently normal MRI scan does not rule out multiple myeloma.<sup>16,33</sup>

## ■ MANAGEMENT PRINCIPLES

Management may require addressing one or all of the following:

- Acute fracture pain
- Chronic mechanical sequelae
- Prevention of additional compression fractures, including assessing and treating underlying osteoporosis.<sup>34</sup>

### ■ MANAGEMENT OF ACUTE FRACTURE PAIN

If the patient is neurologically stable, medical treatment of an acute fracture should emphasize pain relief, with limited bed rest, appropriate analgesics, bracing, and physical strengthening.<sup>18,34</sup>

#### **Avoid prolonged bed rest**

The hazards of prolonged bed rest in the elderly include deconditioning, accelerated bone loss, deep venous thrombosis, pneumonia, decubitus ulcers, disorientation, and depression.

#### **Analgesics**

Analgesics, in addition to relieving pain, may permit earlier ambulation and avoidance of the complications of prolonged bed rest.<sup>2,24,26</sup>

**Calcitonin**, given subcutaneously, intranasally, or rectally, has an analgesic effect in compression fractures due to osteoporosis<sup>35–40</sup> and in patients with metastatic bone pain.<sup>41–45</sup>

The analgesic activity of calcitonin may be related to increased levels of plasma endorphins.<sup>44,46</sup> Recently, Yoshimura<sup>47</sup> and Lyritis and Trovas<sup>48</sup> demonstrated that calcitonin may exert its action via serotonergic receptors in the spinal cord.

In osteoporotic vertebral compression fractures, calcitonin also inhibits osteoclast function, thereby preventing bone resorption.<sup>49,50</sup>

**Opioid analgesics** may be necessary in some patients to relieve pain adequately. However, in older, immobilized patients, opioid-associated constipation and cognitive impairment are significant concerns,<sup>18,34</sup> and a prophylactic laxative program should be started at the same time the opioid is prescribed.

**In older patients, prescribe a laxative when starting opioids**



When prescribing an opioid, caution the spouse or caregiver to observe the patient carefully for cognitive impairment and to provide a protected environment to reduce the risk of falling.

**Avoid nonsteroidal anti-inflammatory drugs (NSAIDs).** In general, pure analgesics, opioid or non-opioid, are preferable to NSAIDs, particularly in older patients with vertebral compression fracture. The risk of NSAID-related gastropathy, renal insufficiency, and congestive heart failure is significantly increased in the elderly.<sup>18,51–55</sup>

### Bracing

Bracing is commonly used in acute nonsurgical management. Spinal orthoses help control pain and promote healing by stabilizing the spine. By restraining forward flexion, they reduce the load on the anterior column and the vertebral body.

Definitive studies comparing different types of orthoses are lacking, but in general, all spine orthoses, whether made of cloth, metal, or plastic, or whether rigid or flexible, use a three-point pressure system. If possible, the orthosis should be lightweight and easy for the patient to use.

For lower thoracic and lumbar fractures, a Jewett hyperextension orthosis or cruciform anterior spinal hyperextension (CASH) orthosis is typically used.

The optimal duration of bracing is not well studied. Two to 3 months is adequate for most patients. Excessively prolonged bracing may lead to weakening of trunk muscles, skin breakdown, increased segmental motion at the upper and lower end of the orthosis, and diminished pulmonary capacity.<sup>56–58</sup>

### Strengthening program

As the acute fracture pain subsides, a walking program can begin, with gentle strengthening exercises focusing on spinal extensor muscles.<sup>45</sup> In some patients, a home physical therapist can encourage and assist with early ambulation and mobilization.

A carefully supervised rehabilitation program should be started after 3 to 4 months to more aggressively strengthen the spinal extensor and abdominal muscles.<sup>34,59</sup>

## ■ VERTEBROPLASTY AND KYPHOPLASTY

Two new, minimally invasive surgical techniques are used to treat vertebral compression fractures: percutaneous vertebroplasty and kyphoplasty.

### Percutaneous vertebroplasty

Percutaneous vertebroplasty<sup>60</sup> involves placing a bone marrow biopsy needle into the compressed vertebra via a posterior approach, guided by fluoroscopy or computed tomography. Methylmethacrylate cement is then injected.

The procedure stabilizes the fracture, and it provides nearly immediate pain relief in 90% to 100% of patients. It does not, however, improve the deformity.<sup>61–64</sup>

Complications occur in fewer than 10% of patients and include radiculopathy, infection, and cord compression. Since the cement is injected under relatively high pressure, leakage outside of the vertebrae is relatively common, occurring in 50% to 67% of patients.<sup>61,63,65–67</sup> Leakage of methylmethacrylate cement into the epidural space may cause neurologic deficit. Other complications include cement leakage from a vertebra to the paravertebral muscles (ie, psoas muscle), causing severe pain due to a localized thermal reaction. In addition, leakage of cement into the venous circulation can produce a generalized toxic reaction. If the cement enters the inferior vena cava, pulmonary embolism can develop.<sup>63–65</sup> However, these complications can be minimized by the use of venography prior to the injection of cement and by using a smaller dose of cement.<sup>68</sup>

### Kyphoplasty

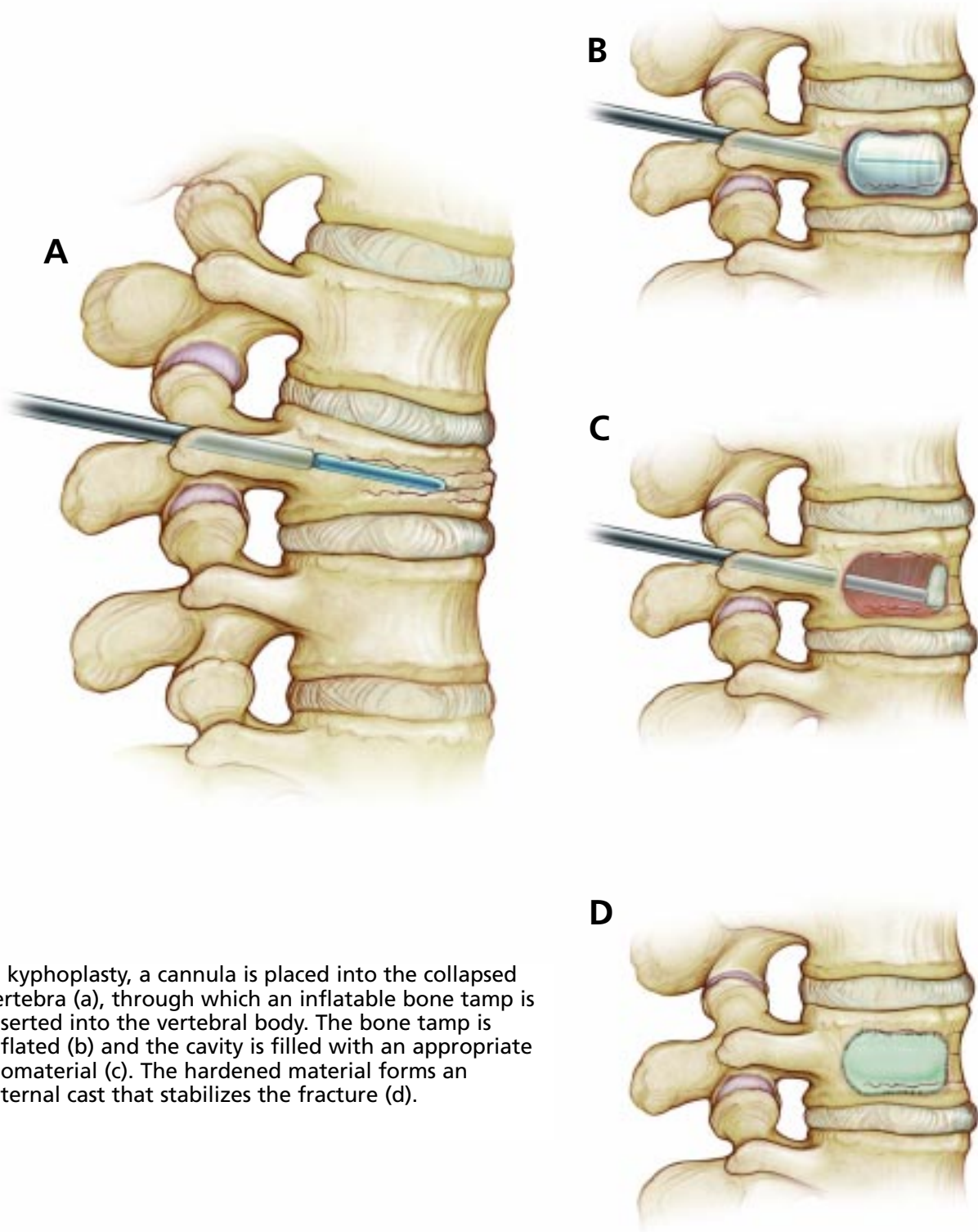
Kyphoplasty was introduced in 1998 for treatment of compression fracture. This procedure involves percutaneous insertion of a needle with an inflatable bone tamp into the fractured vertebra (**FIGURE 4**). Inflation of the bone tamp creates a cavity and re-expands the compressed vertebra. The cavity is then filled with a thick methylmethacrylate mixture under low pressure.

Early experience suggests that more than 90% of patients experience pain relief and prompt functional improvement with this procedure, similar to the results with percutaneous

**Avoid excessive use of braces; 2 – 3 months is enough for most patients**



## ■ Kyphoplasty



In kyphoplasty, a cannula is placed into the collapsed vertebra (a), through which an inflatable bone tamp is inserted into the vertebral body. The bone tamp is inflated (b) and the cavity is filled with an appropriate biomaterial (c). The hardened material forms an internal cast that stabilizes the fracture (d).

CCF  
©2003

**FIGURE 4**

vertebroplasty.<sup>69,70</sup> In addition, kyphoplasty restores vertebral height by almost 50% in approximately 70% of patients. In the other 30% of patients, however, typically those with older fractures, height restoration is not possible.

Complications are uncommon, and cement leakage is less frequent than with vertebroplasty.<sup>61,67,69,70</sup>

### Long-term effectiveness

We do not know yet whether kyphoplasty reduces the frequency of serious sequelae of vertebral compression fracture, nor do we know the long-term consequences of cement in a vertebral body. In addition, the specific indications for kyphoplasty vs vertebroplasty in patients with acute fracture are yet to be determined.

But this much is certain: both vertebroplasty and kyphoplasty can provide prompt relief of incapacitating pain due to vertebral compression fracture,<sup>71</sup> and kyphoplasty may provide the additional significant benefit of restoring vertebral body height, thus avoiding the progressive kyphosis seen with osteoporotic compression fracture. Clearly, patients with acute compression fracture and incapacitating pain that does not respond to good medical treatment should be considered for one of these procedures. If restoration of vertebral body height is an objective, earlier intervention with kyphoplasty seems more likely to be successful.

## LONG-TERM MANAGEMENT

### Chronic pain

Some patients experience complete resolution of acute fracture symptoms within 8 to 12 weeks. Others, however, continue to experience mechanical or myofascial back pain, particularly with prolonged standing or walking. Chronic pain is generally more common in patients with multiple fractures, loss of height, and low bone density. In these patients, it is paramount to continue an active extensor muscle strengthening and stretching program,

as well as a low-impact aerobic conditioning program such as walking or swimming.

In addition to analgesics, nonpharmacologic measures such as transcutaneous electrical nerve stimulation, heat or cold applications, or intermittent bracing may provide temporary relief. The psychological aspects of chronic pain and functional loss should be addressed with counseling and, if indicated, antidepressants.<sup>2,23,34</sup>

### Fracture prevention


Evaluation and management of osteoporosis is an integral part of the management of vertebral compression fracture. Most patients with an acute osteoporotic fracture should be considered for aggressive osteoporosis therapy.<sup>18,72</sup>

Bone densitometry should be performed in patients presenting with compression fractures and previously unsuspected bone loss.<sup>72–75</sup> The National Osteoporosis Foundation recommends that all women with a spinal fracture and a bone mineral density T score less than –1.5 should be treated for osteoporosis.<sup>76</sup>

Dietary calcium and vitamin D supplementation should be optimized.

Bisphosphonates (alendronate, risedronate) reduce the incidence of new vertebral fractures by almost 50%,<sup>77–80</sup> and significantly reduce the risk of hip fracture as well.<sup>77</sup> Raloxifene, a selective estrogen receptor modulator, has been shown to reduce new vertebral fractures by about 68% at 1 year and by about 50% at 3 years.<sup>81,82</sup>

Calcitonin has recently been shown to reduce risk of new vertebral fracture by about one third in women with prevalent vertebral fractures.<sup>72</sup>

Teriparatide (Forteo), is a preparation of recombinant parathyroid hormone given by subcutaneous injection. It has been shown to lower the risk of vertebral fractures and increase bone mineral density in postmenopausal women with osteoporosis,<sup>83</sup> and was recently approved by the US Food and Drug Administration. It acts on osteoblasts to stimulate new bone formation. 

## REFERENCES

1. Cooper C, Atkinson EJ, O'Fallon WM, Melton LJ III. Incidence of clinically diagnosed vertebral fractures: a population-based study in Rochester, Minnesota, 1985–1989. *J Bone Miner Res* 1992; 7:221–227.
2. Silverman SL. The clinical consequences of vertebral compression fracture. *Bone* 1992; 13(suppl 2):S27–S31.
3. Holbrook TL, Grazier K, Kelsey JL, Stanffer RN. The frequency of occurrence, impact and cost of musculoskeletal

**Vertebroplasty and kyphoplasty can relieve severe pain promptly**





- condition in the United States. Chicago: American Academy of Orthopedic Surgeons, 1985.
4. **Riggs L, Melton LJ.** The worldwide problem of osteoporosis. Insights afforded by epidemiology. *Bone* 1995; 17(suppl 5):S055–S115.
  5. **Cooper C.** The crippling consequences of fractures and their impact on quality of life. *Am J Med* 1997; 103:125–195.
  6. **Patel U, Skingle S, Campbell GA, Crisp AJ, Boyle IT.** Clinical profile of acute vertebral compression fractures in osteoporosis. *Br J Rheumatol* 1991; 30:418–421.
  7. **Baba H, Maezawa Y, Kamitani K, et al.** Osteoporotic vertebral collapse with late neurologic complications. *Paraplegia* 1995; 33:281–289.
  8. **Heggeness MH.** Spine fracture with neurological deficit in osteoporosis. *Osteoporosis Int* 1993; 3:215–221.
  9. **Kaplan PA, Orton DF, Asleson RJ.** Osteoporosis with vertebral compression fractures, retropulsed fragments, and neurologic compromise. *Radiology* 1987; 165:533–535.
  10. **Lee YL, Yip KM.** The osteoporotic spine. *Clin Orthop* 1996; 323:91–97.
  11. **Nevitt M, Ettinger B, Black D, et al.** The association of radiographically detected vertebral fractures with back pain and function: a prospective study. *Ann Intern Med* 1998; 128:793–800.
  12. **Lukert B.** Vertebral compression fractures: How to manage pain, avoid disability. *Geriatrics* 1994; 49:22–26.
  13. **Gold DJ.** The clinical impact of vertebral fractures: quality of life in women with osteoporosis. *Bone* 1996; 18:1855–1895.
  14. **Smith K, Bradley S, Kauffman C.** Fever of unknown origin in the elderly: lymphoma presenting as vertebral compression fractures. *J Am Geriatr Soc* 1994; 42:88–92.
  15. **Naul GL, Peet GP, Maupin BW.** Avascular necrosis of the vertebral body: MR imaging. *Radiology* 1989; 172:219–222.
  16. **Lecouvet F, Malghem J, Michaux L, et al.** Vertebral compression fractures in multiple myeloma. Part II. Assessment of fracture risk with MR imaging of spinal bone marrow. *Radiology* 1997; 204:201–205.
  17. **Mouloupoulos L, Yoshimitsu K, Johnston D, Leeds N, Libshitz H.** MR prediction of benign and malignant vertebral compression fractures. *J Mag Reson Imaging* 1996; 6:667–674.
  18. **Lyles KW.** Management of patients with vertebral compression fractures. *Pharmacotherapy* 1999; 19:215–245.
  19. **Leech JA, Dulberg C, Kellie S, Pattee L, Gay J.** Relationship of lung function to severity of osteoporosis in women. *Am Rev Respir Dis* 1990; 141:68–71.
  20. **Schlaich C, Minne HW, Bruckner T, et al.** Reduced pulmonary function in patients with spinal osteoporotic fractures. *Osteoporos Int* 1998; 8:261–267.
  21. **Benzel EC.** Biomechanics of Spine Stabilization, 1st ed. Illinois: AANS Publications, 2001:74–75.
  22. **Lindsay R, Silverman SL, Cooper C, et al.** Risk of new vertebral fracture in the year following a fracture. *JAMA* 2001; 285:320–323.
  23. **Lyles K, Gold D, Shipp KM, Pieper CF, Martinez S, Mulhausen PL.** Association of osteoporotic vertebral compression fractures with impaired functional status. *Am J Med* 1993; 94: 595–601.
  24. **Licata A.** Quality of life of osteoporotic patients: the impact of vertebral compression fractures. *Advances in Osteoporotic Fracture Management* 2001; 1:2–6.
  25. **Oleksik A, Lips P.** Health related quality of life in postmenopausal women with low BMD with or without prevalent vertebral fractures. *J Bone Min Res* 2000; 15:1384–1392.
  26. **Heany RP.** The natural history of vertebral osteoporosis. Is low bone mass an epiphenomenon? *Bone* 1992; 13:523–526.
  27. **Kado D, Browner W, Palermo L, et al.** Vertebral fractures and mortality in older women. A prospective study. *Arch Intern Med* 1999; 159:1215–1220.
  28. **Van Gelderen WF, al-Hindawi M, Gale RS, Steward AH, Archibald CG.** Significance of short tau inversion recovery magnetic resonance sequence in the management of skeletal injuries. *Australas Radiol* 1997; 41:13–15.
  29. **Gates GF.** SPECT bone scanning of the spine. *Semin Nucl Med* 1998; 28:78–94.
  30. **Maynard SA, Jensen ME, Schweickert PA, Marx WF, Short JG, Kallmes DF.** Value of bone scan imaging in predicting pain relief from percutaneous vertebroplasty in osteoporotic vertebral fractures. *Am J Neuroradiol* 2000; 21:1807–1812.
  31. **Baur A, Stabler A, Bruning R, et al.** Diffusion-weighted MR imaging of bone marrow differentiation of benign vs pathologic compression fractures. *Radiology* 1998; 207:349–356.
  32. **Rupp R, Ebraheim N, Coombs RJ.** Magnetic resonance imaging differentiation of compression spine fractures or vertebral lesions caused by osteoporosis or tumor. *Spine* 1995; 20:2499–2504.
  33. **Lecouvet F, Vande Berg B, Maldague B, et al.** Vertebral compression fractures in multiple myeloma. Part I. Distribution and appearance at MR imaging. *Radiology* 1997; 204:195–199.
  34. **Rapado A.** General management of vertebral fractures. *Bone* 1996; 18:1915–1965.
  35. **Lyreris GP, Tsakalakis N, Magrases B, Karachaluo T, Yiatzides A, Tsekura M.** Analgesic effect of salmon calcitonin in osteoporotic vertebral fractures: a double-blind placebo controlled clinical study. *Calcif Tiss Int* 1991; 49:369–372.
  36. **Pun KK, Chan LWL.** Analgesic effect of intranasal salmon calcitonin in the treatment of osteoporotic vertebral fractures. *Clin Ther* 1989; 11:205–209.
  37. **Lyreris GP, Ioannides GV, Karachaluo T, et al.** Analgesic effect of salmon calcitonin suppositories in patients with acute pain due to recent osteoporotic crush fractures: a prospective double-blind, randomized, clinical study. *Clin J Pain* 1999; 15:284–289.
  38. **Rifat SF, Kiningham RB, Pegg JF.** Calcitonin in the treatment of osteoporotic bone pain. *J Fam Prac* 1992; 35:93–96.
  39. **Lyreris GP, Paspate I, Karachakor T, et al.** Pain relief from nasal salmon calcitonin in osteoporotic vertebral fractures. *Acta Orthopaedic Scandinava* 1997; 275:112–114.
  40. **Maksymowych WP.** Managing acute osteoporotic vertebral fractures with calcitonin. *Can Fam Physician* 1998; 44:2160–2166.
  41. **Kreeger L, Hutton-Potts J.** The use of calcitonin in the treatment of metastatic bone pain. *J Pain Symptom Manage* 1999; 17:2–5.
  42. **Szanto J, Ady N, Jozsef S.** Pain killing with calcitonin nasal spray in patients with malignant tumors. *Oncology* 1992; 49:189–182.
  43. **Szanto J, Jozsef S, Rado J, Jahos E, Hindy I, Eckhardt S.** Pain killing with calcitonin nasal spray in patients with malignant tumors. *Oncology* 1986; 43:69–72.
  44. **Azria M.** Possible mechanism of the analgesic action of calcitonin. *Bone* 2002; 30(suppl 1):S80–S83.
  45. **Roth A, Kolark K.** Analgesic activity of calcitonin in patients with painful osteolytic metastases of breast cancer. Results of a controlled randomized study. *Oncology* 1966; 43:283–287.
  46. **Laurian L, Oberman Z, Graf E, Gilad S, Hoerer E, Simantov R.** Calcitonin induced increased ACTH,  $\beta$ -endorphin and cortisol secretion. *Horm Metab Res* 1981; 18:268–271.
  47. **Yoshimura M.** Analgesic mechanisms of calcitonin. *J Bone*



- Min Metab 2000; 18:230–233.
48. **Lyritis GP, Trovas G.** Analgesic effects of calcitonin. *Bone* 2002; 30(suppl 1):71–74.
  49. **Azria M.** The Calcitonins, Physiology and Pharmacology. Basel, Switzerland: Karger, 1989.
  50. **Chambers TJ, Dunn CJ.** Pharmacological control of osteolytic mobility. *Calcif Tiss Int* 1983; 35:566–579.
  51. **Whelton A, Schulman G, Wallemork C, et al.** Effect of celecoxib and naproxen on renal function in the elderly. *Arch Intern Med* 2000; 160:1465–1470.
  52. **Wolfe MM, Lichtenstein DR, Singh G.** Medical progress: gastrointestinal toxicity of nonsteroidal anti-inflammatory drugs. *N Engl J Med* 1999; 340:1888–1899.
  53. **Heerdink ER, Leufkens HG, Herings RN, Ottervanger JP, Stricker BH, Bakker A.** NSAIDs associated with increased risk of congestive heart failure in elderly patients taking diuretics. *Arch Intern Med* 1998; 158:1108–1112.
  54. **Feenstra J, Heerdink ER, Grobbee DE, Stricker BH.** Association of nonsteroidal anti-inflammatory drugs with first occurrence of heart failure and with relapsing heart failure: The Rotterdam Study. *Arch Intern Med* 2002; 162:265–270.
  55. **Page J, Henry D.** Consumption of NSAIDs and the development of congestive heart failure in elderly patients: an underrecognized public health problem. *Arch Intern Med* 2000; 160:777–784.
  56. **Bonner FJ, Chestnut CH, Fitzsimmons A, et al.** Osteoporosis. In: Delisa JA, Gans BM, Bockenek WL, et al, editors. *Rehabilitation Medicine: Principles and Practice*, 3rd ed. Philadelphia: Lippincott-Raven, 1998:1453–1476.
  57. **Fisher SV, Winter RB.** Spinal orthoses in rehabilitation. In: Braddom RL, editor. *Physical Medicine and Rehabilitation*. Philadelphia: W.B. Saunders Company, 1996:359–368.
  58. **Stillo JV, Stein AB, Ragnarson KT.** Low back orthoses. *Phys Med Rehab Clin North Am* 1992; 3:57–94.
  59. **Sinaki M.** Musculoskeletal rehabilitation. In: Riggs BL, Melton LJ, editors. *Osteoporosis: Etiology, Diagnosis, and Management*, 2nd ed. Philadelphia: Lippincott-Raven, 1995:435–473.
  60. **Galibert P.** Note préliminaire sur le traitement des angiomes vertébraux par vertébroplastie acrylique. *Neurochirurgie* 1987; 33:166–167.
  61. **Garfin S, Yuan H, Reiley M.** New technologies in spine. Kyphoplasty and vertebroplasty for the treatment of painful osteoporotic compression fractures. *Spine* 2001; 14:1511–1515.
  62. **Lapras J, Motto LC.** Injection percutanée de méthylméthacrylate dans le traitement de l'ostéoporose et ostéolyse vertébrale grave. *Ann Chir* 1987; 43:371–375.
  63. **Mathis J, Barr JD, Belkoff S, et al.** Percutaneous vertebroplasty: a developing standard of care for vertebral compression fractures. *Am J Neuroradiol* 2001; 22:373–381.
  64. **Jensen ME, Evans AJ, Mathis JM, et al.** Percutaneous polymethylmethacrylate vertebroplasty in the treatment of osteoporotic vertebral body compression fractures: technical aspects. *Am J Neuroradiol* 1997; 18:1897–1904.
  65. **Cotten A, Bounty N, Cortet B, et al.** Percutaneous vertebroplasty: state of the art. *Radiographics* 1998; 18:311–323.
  66. **Daramond H.** Percutaneous vertebroplasty with polymethylmethacrylate: technique, indications, and results. *Radiol Clin North Am* 1998; 36:533–546.
  67. **Watts NB, Harris ST.** Treatment of painful osteoporotic vertebral fractures with percutaneous vertebroplasty or kyphoplasty. *Osteoporosis Int* 2001; 12:429–437.
  68. **Ryu KS, Park CK, Kim MC, Kang JK.** Dose-dependent epidural leakage of polymethylmethacrylate after percutaneous vertebroplasty in patients with osteoporotic vertebral compression fractures. *J Neurosurg* 2002; 96(1 Suppl):56–61.
  69. **Lieberman IH, Dudeney S, Reinhardt M-K, Bell G.** Initial outcome and efficacy of "kyphoplasty" in the treatment of painful osteoporotic vertebral compression fractures. *Spine* 2001; 26:1631–1638.
  70. **Phillips FM, Paul R, Lieberman I.** Kyphoplasty for the treatment of osteoporotic and osteolytic vertebral compression fractures. *Adv Osteo Fract Manage* 2001; 1:7–11.
  71. **Garfin S, Reiley M.** Minimally invasive treatment of osteoporotic vertebral body compression fractures. *Spine J* 2002; 2:76–80.
  72. **Marcus R, Wong M, Heath H, Stock JL.** Antiresorptive treatment of postmenopausal osteoporosis: comparison of study designs and outcomes in large clinical trials with fracture as an endpoint. *Endocr Rev* 2002; 23:16–37.
  73. **Milott JL, Green SS, Schapira MM.** Osteoporosis: evaluation and treatment. *Comp Ther* 2000; 26:183–189.
  74. **Lane JM, Russel L, Khan SN.** Osteoporosis. *Clin Orthop* 2000; 372:139–150.
  75. **Wade JP.** Osteoporosis. *Can Med Assoc J* 2001; 165:45–50.
  76. Highlights of the fourth Annual Conference on Osteoporosis, Amelia Island, Florida, February 22–24, 2001. *South Med J* 2001; 94:561–568.
  77. **Black DM, Thompson DE, Bauer DC, et al, for the FIT Research Group.** Fracture risk reduction with alendronate in women with osteoporosis: the Fracture Intervention Trial. *J Clin Endocrinol Metab* 2000; 85:4118–4124.
  78. **Sharpe M, Noble S, Spencer CM.** Alendronate. an update of its use in osteoporosis. *Drugs* 2001; 61:999–1039.
  79. **Reginster J, Minne HW, Sorensen OH, et al, for the Vertebral Efficacy with Risedronate Therapy (VERT) Study Group.** Randomized trial of the effects of risedronate on vertebral fractures in women with established postmenopausal osteoporosis. *Osteoporos Int* 2000; 11:83–91.
  80. **Harris ST, Watts NB, Genant HK, et al, for the Vertebral Efficacy With Risedronate Therapy (VERT) Study Group.** Effects of risedronate treatment on vertebral and nonvertebral fractures in women with postmenopausal osteoporosis: a randomized controlled trial. *JAMA* 1999; 282:1344–1352.
  81. **Ettinger B, Black DM, Mitlak BH, et al, for the Multiple Outcomes of Raloxifene Evaluation (MORE) Investigators.** Reduction of vertebral fracture risk in postmenopausal women with osteoporosis treated with raloxifene: results from a 3-year randomized clinical trial. *JAMA* 1999; 282:637–645.
  82. **Maricic M, Adachi JD, Sarkar S, Wu W, Wong M, Harper KD.** Early effects of raloxifene on clinical vertebral fractures at 12 months in postmenopausal women with osteoporosis. *Arch Intern Med* 2002; 162:1140–1143.
  83. **Neer R, Arnaud C, Zanchetta JR, et al.** Effects of parathyroid hormone (1–34) on fractures and bone mineral density in postmenopausal women with osteoporosis. *N Engl J Med* 2001; 344:1434–1441.

ADDRESS: Daniel J. Mazanec, MD, Director, Spine Center, Rheumatologic & Immunologic Disease, C21, The Cleveland Clinic Foundation, 9500 Euclid Avenue, Cleveland, OH 44195; e-mail: mazanec@ccf.org.