

Osteoporotic vertebral fracture

Anatomy & Pathophysiology

VERTEBRAL COLUMN ANATOMY

- The vertebral column comprises 33 vertebrae divided into five sections: 7 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 4 coccygeal [16].
- The sacral and coccygeal vertebrae are fused, typically allowing for 24 mobile segments [16].
- A typical vertebra comprises an anterior body and a posterior arch that enclose the vertebral canal [16].
- The neural arch is composed of two pedicles laterally and two laminae posteriorly that are united to form the spinous process [16].
- To either side of the arch of the vertebral body is a transverse process and superior and inferior articular processes [16].
- The articular processes articulate with adjacent vertebrae to form synovial joints [16].
- The relative orientation of the articular processes accounts for the degree of flexion, extension, or rotation possible in each segment of the vertebral column [16].
- The spinous and transverse processes serve as levers for the numerous muscles attached to them [16].
- The length of the vertebral column averages 72 cm in men and 7 to 10 cm less in women [16].
- The vertebral canal extends throughout the length of the column and provides protection for the spinal cord, conus medullaris, and cauda equina [16].

INTERVERTEBRAL DISK ANATOMY

- The intervertebral disk connects adjacent vertebral bodies [6].
- The adjacent vertebral bodies, the disk, and the facet joints constitute the functional spinal unit that provides mechanical stability and allows physiologic motion [6].
- The intervertebral disks run between vertebral bodies from C2 to S1 and function to resist loads on the spine and provide stability [18].
- The disks contribute up to one-third of the height of the spinal column [18].

- The disk consists of the cartilaginous end plates of the vertebral bodies, the outer annulus fibrosus, and the inner nucleus pulposus [18].
- The end plate serves as a point of attachment of the disk to the superior and inferior surfaces of the vertebral bodies [18].
- The end plate is a thin layer of hyaline cartilage [18].
- The nucleus pulposus is centrally located and confined by the end plates and the annulus fibrosus [6].
- The nucleus pulposus resists compressive loads, dampens mechanical loads, and evenly distributes forces onto the end plates [6].
- The nucleus pulposus is the remnant of the embryonic notochord and comprises the gelatinous center of the intervertebral disk [18].
- The extracellular matrix of the nucleus pulposus is composed primarily of type II collagen and aggrecan, which makes it relatively hydrophilic [18].
- The nucleus pulposus serves to resist axial loads as well as provide height to the intervertebral disk [18].
- The annulus fibrosus is peripheral to the nucleus pulposus and confines the nucleus pulposus [6].
- The annulus fibrosus is designed to resist tensile loads, allow spinal motion, provide mechanical connection between the vertebrae, and confine the nucleus pulposus [6].
- The annulus fibrosus consists of concentrically layered fibrous cartilage lamellae primarily composed of type I collagen [18].
- The fibers of the annulus fibrosus run in alternating oblique trajectories [18].
- The annulus fibrosus resists tensile forces within the spine, including those due to the compression of the nucleus pulposus [18].
- The end plates form the interface between the vertebrae and the disk and define the upper and lower boundaries of the disk [21].
- The central portion of the end plate provides a major pathway for nutrients from the vertebral bodies to diffuse into the disk [21].

DISK PHYSIOLOGY AND PATHOPHYSIOLOGY

- In a normal healthy lumbar disk, large aggregating proteoglycans (aggrecan and versican) constitute a high percentage of the dry weight in the nucleus [21].
- Glycosaminoglycan molecules (keratan sulfate and chondroitin sulfate) decorate the aggrecan and versican core protein and are highly negatively charged [21].
- The highly negatively charged glycosaminoglycans create a highly hydrophilic matrix that attracts H₂O molecules [21].
- The attraction of H₂O molecules provides swelling pressure that counteracts the axial loads encountered by the disk [21].
- The matrix is viscoelastic and therefore dissipates mechanical energy and is subject to creep [21].
- Disk height is less at the end of each day due to creep [21].

- The adult intervertebral disk is avascular and derives its nutrition through diffusion from terminal capillaries in the vertebral bodies just below the end plates [18].
- In the adult, the blood supply ends at the bony end plate of the vertebral body and the outer annulus fibrosus [21].
- Most of the disk is considered immunologically isolated due to its avascularity [21].
- Nutrients are supplied to the disk cells primarily through diffusion [21].
- As the disk gets larger during development, the distances that nutrition must diffuse across become larger, further impeding nutritional supply to the disk cells [21].
- The decrease in nutritional transport is thought to contribute to disk degeneration [21].
- Innervation of the intervertebral disk is confined to the peripheral annulus fibrosus [21].
- The sinuvertebral nerve, which arises from the dorsal root ganglion, innervates the outer annulus fibrosus [21].
- In some degenerated disks with fissures, nerve fibers may be found deeper in the annulus fibrosus [21].
- The normal nucleus pulposus is not innervated [21].
- Pain sensation from the disk arises only from the annulus fibrosus [21].
- The nucleus pulposus can generate molecules such as cytokines and proteinases that can lead to pain [21].
- With normal ageing, glycosaminoglycan production diminishes, leading to gradual desiccation of the disc [19].
- The annulus fibrosus develops fissures and disc nuclear material may prolapse through during degeneration [19].
- The discs lose height and bulge beyond the margins of the vertebral bodies during degeneration [19].
- Disc protrusion against the ligaments causes formation of marginal osteophytes [19].
- Adjacent vertebral end plates ossify and become sclerotic while fatty change occurs in the subchondral bone marrow during spondylosis [19].
- Disc degeneration results in altered biomechanics and increased loading forces on the facet joints [19].
- Facet joint osteoarthritis may lead to osteophyte encroachment into the canal causing spinal lateral recess stenosis [19].
- The ligamentum flavum thickens, which contributes to stenosis, while the disc bulges from anteriorly into the spinal canal [19].

OSTEOPOROSIS PATHOPHYSIOLOGY

- Osteoporosis is the most common metabolic bone disease resulting from imbalance between bone formation and bone resorption [2].
- Spinal fractures are the most common manifestation of osteoporosis [2].
- Only one in three patients with spinal fractures are symptomatic [2].

- In elderly patients, osteoporosis-related spinal fractures have similar morbidity and mortality as hip fractures [2].
- Osteoporosis and low bone mass are present in about 50% of elective spine patients older than 50 years [2].
- Osteoporosis and low bone mass negatively affect clinical outcomes and are associated with increased complications and revision surgery [2].
- Vitamin D deficiency is present in the majority of spine patients [2].

Clinical Presentation

- A history of fragility fracture significantly increases the risk of another fracture [15].
- The relative risk of a subsequent fracture is two to three times higher in women with a prior fragility fracture [15].
- The relative risk of a subsequent fracture is up to six times higher in men with a prior fragility fracture [15].
- A history of greater than a single vertebral fracture significantly increases the risk of further vertebral fractures [15].
- In a meta-analysis of nontreated patients enrolled in vertebroplasty studies, 18% had a secondary fracture within 12 months [15].

Investigations

IMAGING MODALITIES

- Dual energy x-ray absorptiometry (DXA) is the benchmark to assess bone mineral density (BMD) [25].
- DXA measures areal BMD in g/cm² of the proximal femur, lumbar spine, and distal radius [25].
- DXA is accurate and precise when calibrated and performed properly [25].
- DXA involves a very low radiation dose [25].
- BMD is reported as a standard deviation difference to a reference standard [25].
- T-score is the reference standard for young healthy females [25].
- Z-score is the reference standard for age- and gender-matched subjects [25].
- Vertebral fracture assessment (VFA) can be performed at the time of DXA [25].
- VFA identifies occult vertebral fracture in 20% to 30% of cases [25].
- VFA is useful to change a diagnosis from low bone mass (osteopenia) to osteoporosis [25].
- Opportunistic CT uses CT data to estimate bone status [25].
- CT is based on the attenuation coefficient called the Hounsfield unit (HU) [25].
- Hounsfield units are related to BMD and can be used to estimate BMD and the presence of osteoporosis [25].

- PACS tools can calculate mean HU for any elliptical region of interest [25].
- Most osteoporotic vertebral fractures can be diagnosed by plain radiographs or CT [26].
- MRI can show edema in the vertebral body to indicate a recent fracture when age determination is required [26].
- An acute measured height change of greater than 1 inch is suggestive of an acute vertebral fracture [26].

LABORATORY AND PREOPERATIVE ASSESSMENT

- Greater than 75% of patients older than 50 years having elective spine surgery have vitamin D insufficiency or deficiency [14].
- Vitamin D deficiency is linked to increased pain severity in spinal stenosis [14].
- Ravindra demonstrated slower fusion and lower rates of success in vitamin D-deficient patients [14].
- Kim found that baseline low vitamin D was associated with worse Oswestry Disability scores at follow-up [14].
- Vitamin D deficiency is treatable but takes 6 weeks [14].
- Osteoporosis is linked to subsidence of cages, pedicle screw loosening, proximal junction failure, poorer fusion rates, increased spondylolisthesis after laminectomy, and higher rates of revision surgery [14].
- Bjerke reviewed 140 lumbar fusion patients and found that 10 were osteoporotic and 59% had low bone mass [14].
- Nonunion was 50% in osteoporotic patients compared with 18% in those with low bone mass or normal BMD [14].
- Osteoporosis-related complications occurred in 23% of patients with normal BMD, 28% of patients with low bone mass, and 46% of osteoporotic patients [14].
- Complication rates worsened relative to BMD when more than single-level fusion was performed [14].
- The AOA suggests using the same principles as outlined for secondary fracture prevention for preoperative bone health optimization [14].
- Inclusion criteria for preoperative bone health optimization assessment include all patients having thoracolumbar surgery who are older than 50 years [14].
- Preoperative patients are recommended to consume vitamin D3 2,000 U daily and 1,200 mg calcium in the diet [14].
- Preoperative patients should be assessed for fall risk and considered for physical therapy if warranted [14].
- Patients who do not need DXA or who screen negative for DXA should undergo surgery [14].
- Patients with low bone mass or osteoporosis should be considered for preoperative bone health optimization [14].
- If medically indicated, patients are treated with diphosphonate or anabolic medication before surgery [14].
- The duration of preoperative treatment is unknown, but effects of bone strength and physiology are seen within 2 months [14].

- A minimum of 3 months of preoperative treatment is recommended if clinically possible before surgery [14].
- Longer treatment up to 9 months should be considered for multilevel or high-risk cases such as osteotomy [14].
- Antiosteoporosis medications should be continued postoperatively [14].
- Multiple RCTs comparing biphosphonates and placebo in patients undergoing lumbar spine fusion show improved clinical outcomes, radiologic outcomes, and lower risk of complications [14].
- Biphosphonates do not appear to be associated with any impairment of bone health [14].
- One RCT and multiple cohort studies show that teriparatide can lead to improved clinical outcomes, radiologic outcomes, and lower risk of complications in spinal fusion patients [14].

Treatment

NON-OPERATIVE MANAGEMENT

- The initial treatment of osteoporotic vertebral fractures is nonsurgical [2].
- Secondary fracture prevention is performed in less than 20% of cases following osteoporosis-related fractures [2].
- Secondary fracture prevention includes education, assessment of bone health, nutritional supplements, weight-bearing exercise, fall prevention, and pharmaceutical medications if indicated [2].
- A history of fragility fracture increases the relative risk of another fracture by two to three times in women and up to six times in men [15].
- Secondary treatment was given in 10% of patients in a Medicare database analysis but was associated with a reduced risk of fracture by 40% [15].
- The American Orthopaedic Association (AOA) Own the Bone program is located in all states and 150 sites in the United States [15].
- The AOA Own the Bone program significantly improves compliance with treatment recommendations after fragility fracture [15].
- A prospective randomized controlled non-inferiority trial found that rigid brace, soft brace, and no brace treatments for osteoporotic compression fractures without neurologic injury had comparable outcomes [1].
- Vitamin D deficiency is present in the majority of spine patients and should be corrected after fracture and before elective surgery [2].
- Routine use of vitamin D (1,000 to 2,000 IU/day) and calcium supplementation for all spine fusion patients aged 65 years or older may help avoid nonunion and infection [28].
- Target serum 25-hydroxyvitamin D levels are 30 ng/mL [28].

OPERATIVE MANAGEMENT: CEMENT AUGMENTATION

- Vertebroplasty or kyphoplasty is considered for osteoporotic vertebral fracture in patients who are hospitalized for pain, those who do not improve with nonoperative care, or those who have progressive collapse [2].
- A 2009 multicenter trial by Kallmes et al. found that vertebroplasty and a simulated procedure without cement resulted in similar improvements in pain [29].
- A 2009 multicenter, randomized, double-blinded placebo-controlled trial by Buchbinder et al. identified no clinical benefit to vertebroplasty compared to a simulated procedure at follow-up visits ranging from 1 week to 6 months [29].
- A multicenter European randomized control trial by Klazen et al. concluded that vertebroplasty was safe and provided immediate and sustained pain relief and improvement in quality of life to a significantly greater degree than nonsurgical treatment [29].
- A randomized control study by Boonen et al. showed that kyphoplasty and vertebroplasty significantly reduced pain, improved early mobility, and enhanced short-term quality of life compared to noninvasive management options [29].
- A systematic review by Taylor et al. showed that kyphoplasty and vertebroplasty significantly reduced pain, improved early mobility, and enhanced short-term quality of life compared to noninvasive management options [29].
- Balloon kyphoplasty may correct the loss of vertebral body height, a predictor of progressive kyphosis, but this has only been confirmed on a limited basis for kyphoplasty and not for vertebroplasty [29].
- Vertebroplasty and kyphoplasty are largely equivalent in their ability to provide pain relief and functional improvement, with little advantage gained by performing kyphoplasty given its significantly greater cost [29].
- A Medicare database analysis by Edidin et al. identified lower mortality (39% vs. 50%) in patients treated with vertebroplasty compared to patients treated noninvasively [29].
- A 2018 Cochrane Review by Buchbinder et al. analyzing 21 randomized and quasi-randomized controlled trials concluded that current high- to moderate-quality evidence does not support a role for vertebroplasty in the routine treatment of acute or subacute osteoporotic vertebral fractures [29].
- The 2018 Cochrane Review by Buchbinder et al. could not identify sufficient evidence to support any clinically relevant benefit to vertebroplasty compared to placebo [29].
- Subgroup analyses in the 2018 Cochrane Review showed that results were not affected by whether the duration of pain was less than or greater than 6 weeks [29].
- Adverse events identified in the 2018 Cochrane Review included thromboembolic events, cement leakage, spinal cord compression, neurologic injury, respiratory failure, and osteomyelitis [29].
- A randomized study by Firanesu et al. comparing vertebroplasty with a placebo (simulated procedure) control group found a similar, statistically significant reduction in pain as measured by visual analog scale (VAS) scores for both groups during 12-month follow-up [29].

PREOPERATIVE BONE HEALTH OPTIMIZATION

- Greater than 50% of patients older than 50 years having elective spine surgery have low bone mass or osteoporosis [14].
- Vitamin D deficiency is treatable but will take 6 weeks [14].
- In a review of 140 lumbar fusion patients by Bjerke, nonunion was 50% in osteoporotic patients compared with 18% in those with low bone mass or normal BMD [14].
- In a review of 140 lumbar fusion patients by Bjerke, osteoporosis-related complications occurred in 23% of patients with normal BMD, 28% in patients with low bone mass, and 46% in osteoporotic patients [14].
- Inclusion criteria for preoperative bone health optimization include all patients having thoracolumbar surgery who are older than 50 years of age [14].
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- Preoperative patients should be assessed for fall risk and consider physical therapy if warranted [14].
- Patients who have low bone mass or osteoporosis should be considered for preoperative bone health optimization [14].
- The author recommends a minimum of 3 months of preoperative treatment if clinically possible, as effects of bone strength and physiology are seen within 2 months [14].
- For multilevel or high-risk cases such as osteotomy, longer treatment up to 9 months should be considered [14].

Complications

- Osteoporosis and vitamin D deficiency are associated with poorer outcomes, recurrent fractures, and higher complication risks [2].
- Osteoporosis and low bone mass negatively affect clinical outcomes and are associated with increased complications and revision surgery in elective spine patients older than 50 years [2].
- Preoperative and postoperative treatment of osteoporosis in spine surgery patients has been shown to improve outcomes and reduce complications [2].

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