The Importance of Bone Health for Spinal Procedures

Justin S. Field, M.D.

Having healthy bones is very important to prevent fractures. Common areas where people sustain broken bones due to fragility are in the spine, hips, and wrists. It is also very important to have healthy bone quality as it pertains to being able to undergo and recuperate from spine surgery. Whether considering a smaller surgery, such as micro-decompression, or a larger reconstruction, such as a bone fusion or disc replacement, adequate bone support and bone healing is necessary for stability of the spine.

Vitamin D Deficiency

Vitamin D deficiency, osteoporosis, and other nutritional and metabolic disorders can contribute to inadequate bone health and prohibit successful healing. Preoperative evaluation should include an assessment of bone health and a screen for problems in calcium metabolism. While inadequate calcium intake has been long known to be an important factor in bone health, vitamin D deficiency is more common than previously recognized and has the potential to result in poor spine health and poor response to treatment.

Vitamin D is a fat-soluble vitamin that is naturally present in very few foods, added to others, and available as a dietary supplement. It is also produced endogenously when ultraviolet rays from sunlight strike the skin and trigger vitamin D synthesis. Vitamin D is necessary for many bodily functions. Vitamin D promotes calcium absorption in the gut and maintains adequate serum calcium and phosphate concentrations to enable normal mineralization of bone. It is also needed for bone growth and bone remodeling by bone formation and remodeling cells. Without sufficient vitamin D, bones can become thin, brittle, or misshapen. Vitamin D sufficiency prevents rickets in children and osteomalacia in adults. Together with calcium, vitamin D also helps protect older adults from osteoporosis. It is very difficult to get adequate vitamin D solely through the diet. If deficient, your vitamin D level can be normalized with the use of prescription strength vitamin D, however this can take several months.

Maintaining a proper Vitamin D level is an important step to ensure that fusion occurs. This is important to help with pain relief from surgery and quicker return of function.

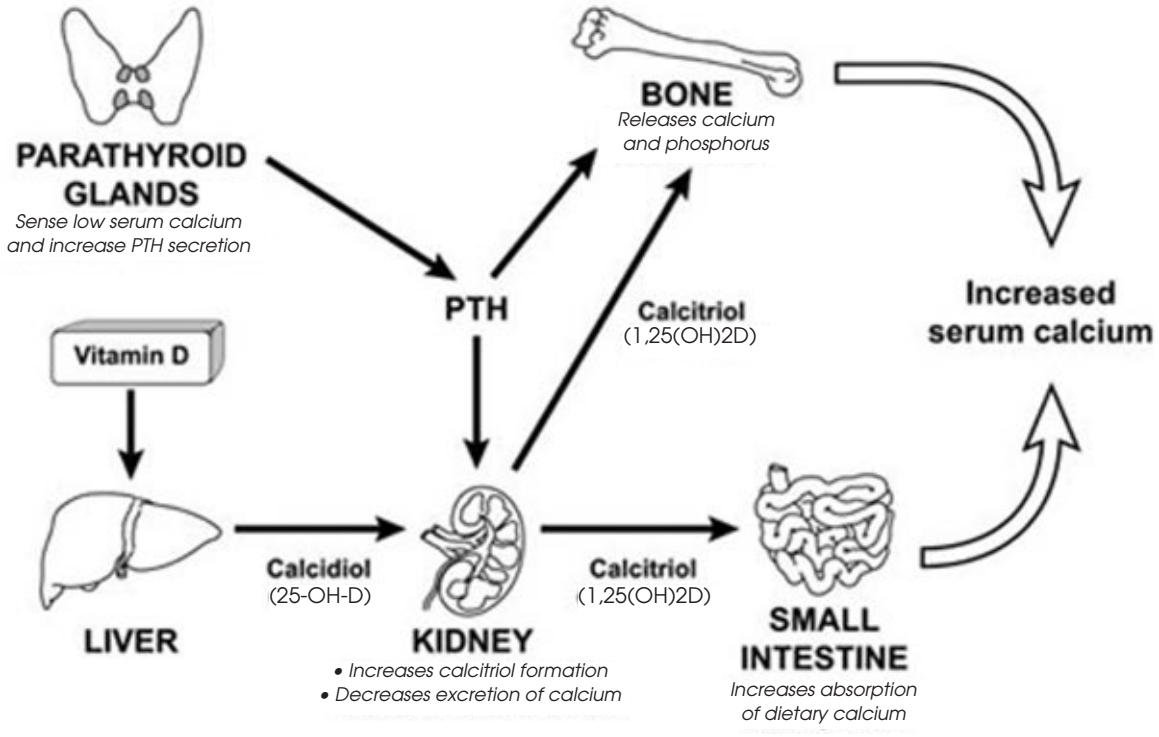

Figure 1. Vitamin D in the endocrine system. *Picture courtesy Jane Higdon, copyright 2008 LPI, used with permission.*

Nicotine

It is also well known that nicotine decreases spine fusion rates and, thus, must be discontinued before bone fusion operations. Fortunately, there are newer, more successful ways to control the smoking urge, and preoperative counseling may help to find the best suited method to quit the tobacco habit and get through the healing process. Second-hand smoke is also harmful to the healing in spine fusion and must be avoided.

Obesity

Obesity has become a major health issue; in fact, it is a national problem. Many disease processes can be dramatically improved or completely reversed with weight loss. More specifically in the orthopedic realm, back pain and knee pain, for example, respond positively to weight reduction. Just losing 10 to 15 pounds can make a huge difference in the reduction of back, hip, and knee pain. Changing eating habits and exercise have been shown to be the most successful strategy for long-term weight reduction and maintenance. Surgical intervention in the spine for obese patients can be fraught with wound complications. Many of these patients are actually nutritionally starved and lack the important nutritional reserves to properly heal. In addition, spine surgery is more difficult on larger patients from the surgeon's perspective because of more difficult access to the pathology, as well as visualization. It is very important to stress weight reduction and change in eating habits to overweight patients. This will also help in their postoperative recovery period to be able to strengthen their core muscles and increase activity.

Osteoporosis

Osteoporosis is a result of negative bone remodeling from enhanced function of the osteoclasts. Because bone formation is the result of coupling between osteoblasts and osteoclasts, anti-resorptive agents that induce osteoclast apoptosis (cell death) may not be effective in spinal fusion surgery, necessitating new bone formation. Therefore, anabolic agents may be more suitable for osteoporotic patients who undergo spinal fusion surgery. The instrumentation and techniques, along with increased pullout strength, may increase fusion rate through rigid fixation. Studies on new osteoinductive materials, methods to increase osteogenic cells, and strengthened and biocompatible osteoconductive scaffolds are necessary to enable osteoporotic patients to undergo spinal fusion. When osteoporotic patients undergo spinal fusion, sur-

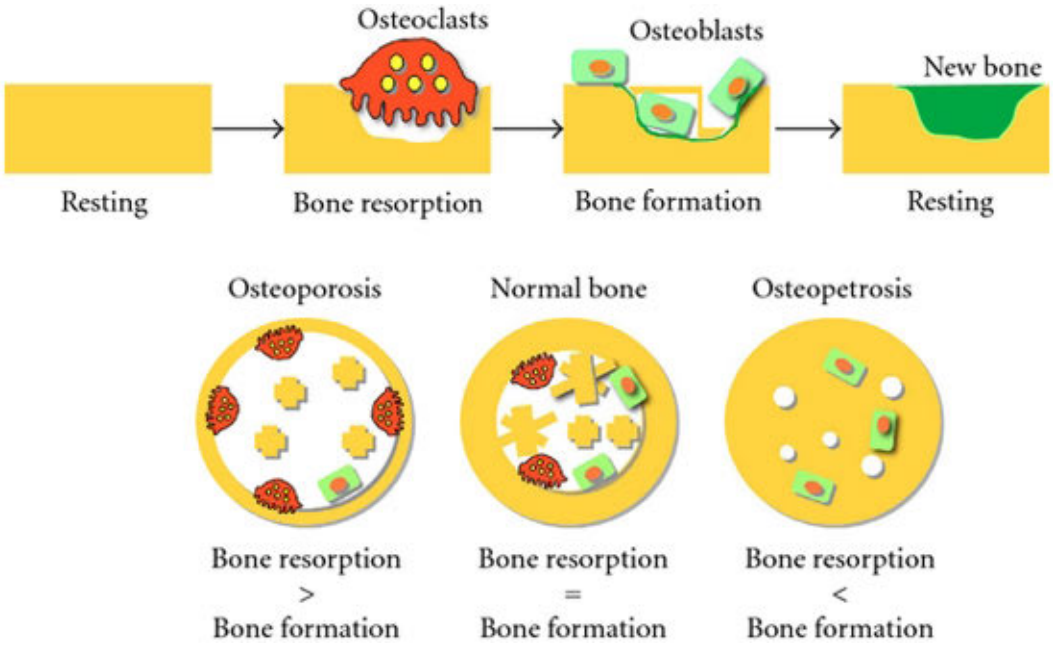

Figure 2. This schematic outlines the bone remodeling cycle and the balance of bone resorption and bone formation. (a) In bone tissue, the osteoblasts are involved in new bone formation, while osteoclasts play a major role in bone resorption. The first step in the bone remodeling cycle is the resorption of existing bone by osteoclasts, followed by formation of the cement line in resorption lacunae and osteoblasts. Each cell type seems to be regulated by a variety of hormones and by local factors. (b) If the balance between bone formation and resorption is lost by the uncontrolled production of regulators, bone structure would be strikingly damaged, and the subject would be susceptible to osteoporosis and osteopetrosis. *Image courtesy of Eijiro Jimi, et. al. The Current and Future Therapies of Bone Regeneration to Repair Bone Defects.* International Journal of Dentistry. *2012, 1–7. (2012).*

geons should consider appropriate osteoporosis medication, instrumentation, and technique.

There are degenerative changes in the intervertebral discs and spinal facet joint capsules in people over 50 years of age that are associated with spinal instability. With increased life expectancy, the elderly desire to be more physically active and have an improved quality of life. Surgical indications for degenerative spinal conditions in elderly patients have increased.[2,17,23,27,31] The surgical outcomes and perioperative complications of spinal fusions in elderly patients can be negatively affected by co-morbidities such as cardiopulmonary disease, renal disease, diabetes mellitus, nutritional disorders, and osteoporosis.[14] Because osteoporosis is strongly associated with poor fusion rate and bone stability, it is crucial to understand the pathophysiology of osteoporosis and its treatment in order to enhance spinal fusion and preserve bone stability. Spinal surgeons must be informed of the appropriate treatment plan for osteoporosis and formulate appropriate strategies for osteoporotic patients who need to undergo spinal fusion surgery.

Osteoporosis is a major global problem because over 10 million people are currently diagnosed with osteoporosis.[28] Although 80% of osteoporotic patients are women, a considerable number of men are also affected.[15,21] The age matched prevalence of osteoporosis is 17–20% of women over 50 years old, 26% over 65 years old and 50% over 85 years old in the United States. In addition, the prevalence of osteoporosis in male and female patients over 50 years old who underwent spinal surgery were 14.5% and 51.3%, respectively.[17] Due to increasing life expectancy, the number of elderly patients with osteoporosis will continue to increase even further.

Due to an increasingly aged population, degenerative spinal stenosis and spondylolisthesis have become more frequently diagnosed.[48,53] Up to 10% of women over 60 years may be affected by degenerative spondylolisthesis and one study presented the rates of male and female patients with spondylolisthesis (degenerative or spondylolytic types) at 14.8% and 66.1%, respectively.[17,40] In elderly patients, iatrogenic cause of instability following spinal surgery may occur because of pre-existing degenerative changes in the facet joints and intervertebral disc. If instability of the spine at the index level is confirmed by preoperative radiological evaluations or when iatrogenic instability occurs, fusion operation should be considered in elderly patients.[34,48,53] Several reports claim that decompression and additional fusions in elderly patients who experienced spinal stenosis and instability, such as spondylolisthesis, produce satisfactory outcome in elderly patients.[16,26,34,46,53] Many studies demonstrated fusion failure which negatively impacted clinical outcomes; fusion rates ranged from 56% to 100%.[11,40,52] Reports on the outcome of lumbar arthrodesis following instrumentation in patients over 60 years of age indicated the prevalence of delayed and collapsed fusion in elderly patients to be higher than that in younger patients. The fusion rates of elderly patients reported were over 90%, and in elderly osteoporotic patients who underwent lumbar arthrodesis with instrumentation, the fusion rates were 89.7% to 95.8%.[16,26,35,41] In other words, old age and osteoporosis are not contraindications in spinal arthrodesis. The number of elderly patients who need spinal surgery will increase, and the prevalence of osteoporosis in elderly patients is high. The existence and severity of osteoporosis should be preoperatively assessed in elderly patients, and an appropriate strategy to facilitate spinal fusion should be formulated.

Biology of Spinal Fusion

Although instrumentation and technique have been improving, non-union still occurs in 5 to 35% of patients who undergo spinal fusion.[8,12] Non-union in spinal surgery frequently leads to unsatisfactory clinical outcomes.[19,25] Therefore, understanding the histological and biologic events in spinal fusion is crucial to spinal surgeons who treat patients with and without osteoporosis. Clinically relevant lumbar fusion animal models are analyzed in several articles to provide information on the methods that facilitate fusion. These articles report that non-decortication of the transverse process did not result in arthrodesis (fusion of the joint), and the primary vascular supply to the fusion mass originated from decorticated bone, not from the adjacent muscle.[9,50] Decortication is the removal of the superfi-

cial portion of cortical bone of the vertebra's posterior elements (spinous process, lamina, and articular facets) to expose the inner vertebral cancellous bone. Decortication can increase tissue metabolism in the interface between bone graft and recipient bed by increasing the vascular supply to this region, accelerating integration between bone graft with the recipient bed, and triggering greater bone neoformation.[55] Intra-membranous bone formation occurs in the area near the transverse processes, and endochondral bone formation, which involves bone formation through a cartilage intermediate, occurs centrally at the interface between the upper and lower halves of the bridging bone.[54]

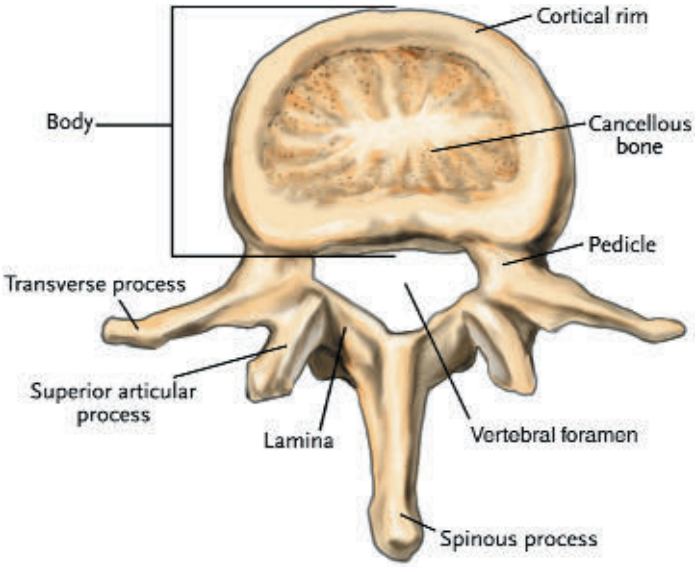

Figure 3. Anatomy of a Lumbar Vertebra. *Image courtesy of Medtronic, Inc.*

Cartilage formed through endochondral ossification has poor vascular supply and low oxygen saturation. However, in the mid and late stages of bone formation, extension of bone formation towards the central zone occurs, and disappearance of cartilage and bone formation occurs in the central area.[9,10,50] The transient cartilaginous area may explain why many non-unions are found to occur in the central zone of a fusion mass. Considering the previous description and three factors for bone formation—osteoconductive scaffold, osteogenic cell, and osteoinductive materials—the characteristics of host beds such as vascularity and quality of bone marrow, the distance of fusion site, and the quality of bone graft should be assessed by the surgeon. Although no publication discusses the histological difference between osteoporosis and non-osteoporosis animal models with spinal fusion, reduced osteoblast ability, poor vascularity, and lower bone marrow quality in the host bed may contribute to non-union in elderly osteoporotic patients. Therefore, surgeons must consider bone graft quality, proper osteoinductive materials, increasing the ability of osteoblasts, and preventing factors that may hinder fusion, including long-term use of non-steroidal anti-inflammatory agents and smoking before performing spinal fusion on elderly osteoporotic patients.

Strategies for Osteoporotic Patients with Spinal Fusion

Osteoporosis reduces bone quality through negative bone remodeling. Low bone quality can reduce the pull-out strength of pedicle screws, and negative bone remodeling can cause delayed bone fusion.[3,18] Therefore, before performing spinal fusion surgery on osteoporotic patients, we should pursue effective strategies to increase the pull-out strength and facilitate positive bone remodeling.

Pharmacotherapeutic Strategies

Osteoporosis, secondary to loss of estrogen, is the cause of negative bone remodeling through reduced function and life span of osteoblasts and the reverse for osteoclasts. In addition, bone remodeling depends on communication between the osteoblast lineage (including lining cells, preosteoblasts, and osteocytes) and the osteoclast lineage. Thus, in order to obtain good fusion rate in osteoporotic patients, we should be aware of the anti-resorptive and anabolic agents.

Bisphophonates

Biphosphonates are typical anti-resorptive agents that include alendronate, ibandronate, etidronate, and pamidronate. The mechanism of bisphosphonate is to promote apoptosis of mature osteoclasts and result in a slow rate of bone remodeling.[32,38,43] Many animal studies present the effects of bisphosphonates on the skel-

etal system. In animal studies that investigated fracture healing and pull-out strength of implants, bisphosphonates did not adversely affect the skeletal system.[39,44] However, according to recent studies, bisphosphonates inhibit or delay spinal fusion through reduced incorporation between grafted bone and host bone.[31,37,49] In other words, the anti-fracture effect of bisphosphonates is not proportional to their efficacy on bone fusion. Therefore, when osteoporotic patients are scheduled to undergo spinal fusion, surgeons must consider the need of using other anti-resorptive or anabolic agents postoperatively.

Recombinant Human Parathyroid Hormone

Only one drug acts as an anabolic agent to osteoporosis—recombinant human parathyroid hormone (PTH). Although high levels of PTH cause decreased bone mineral density (BMD) through increased bone resorption, low and intermittent PTH elevation increases bone formation secondary to its anti-apoptotic effect on osteoblasts.[29,32,33,45] Prior studies concluded that PTH treatment did not increase the incidence of bone tumors such as osteosacroma.[30,42,51] It must be emphasized that the experience of PTH use is so far limited in the United States and Europe to 2 years and 18 months, respectively. If PTH treatment is not followed by anti-resorptive therapy, the increased BMD would be lost.[6,22] Therefore, additional anabolic agents need to be developed to be continuously used in osteoporotic patients. The results of animal studies suggested that PTH enhanced the healing of bone fracture and increased BMD, mechanical strength, and arthrodesis of the spine.[1,4] As concurrent use of alendronate for increasing positive remodeling reduced the anabolic effect of PTH, the use of PTH on osteoporotic patients taking bisphosphonates may be refrained after spine arthrodesis.[7]

Implant Based Strategies

Cancellous bone is more affected by osteoporosis than cortical bone. Therefore, lower BMD has been a major factor in poor screw fixation, screw loosening, and fixation failure.[18] Many techniques have been employed to enhance the pullout strength of the pedicle screw.[24] The preparation for the screw hole or the minimization of tapping the hole can affect the pullout strength in osteoporotic bone, and although the anatomical constraints vary with patients, bigger and longer screws may provide a good solution for fragile bones.[20] The angulation of two screws and screw positioning in areas of higher BMD in the vertebrate may also increase pullout strength.[45,50] Also, to improve the fixation and fatigue strength of instrumentation, screw augmentation with polymethyl methacrylate has yielded favorable outcomes.[5,13] These techniques may enhance bone fusion through stabilization of fusion segments.

Other Strategies

Mesenchymal cells differentiated to osteoblasts are critical for increasing fusion rate. Although the fusion rate achieved by using bone marrow aspirate (BMA) with collagen was inferior to that of using autologous iliac crest bone for posterior lumbar interbody fusion, the fusion rate of posterolateral lumbar fusion with BMA and collagen was comparable to that of autologous bone.[36] However, since there is a low concentration of osteogenic cells in the BMA, it is ineffective as a bone

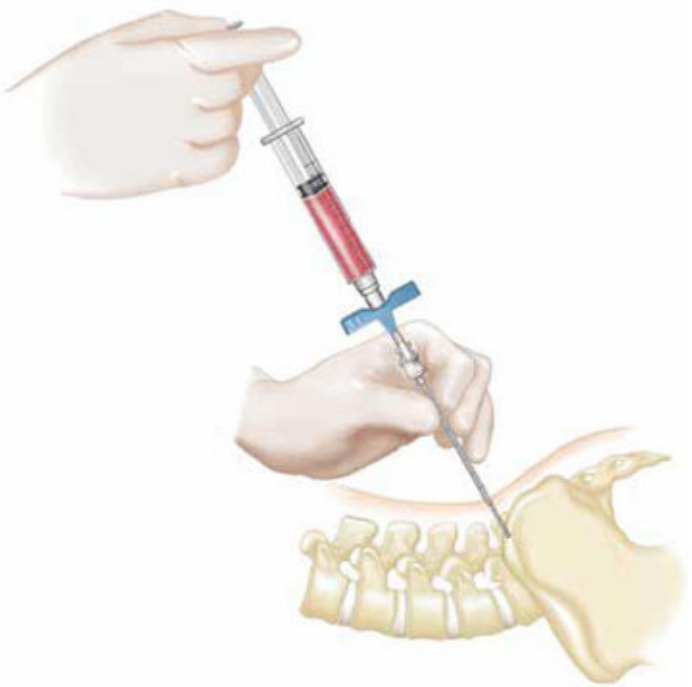

Figure 4. Bone Marrow Aspiration. *Image courtesy of Medtronic, Inc.*

graft substitute. Therefore, investigations for methods of stimulating osteoblast differentiation, expanding the number of osteoblast, and finding new osteoconductive scaffolds with structural strength are needed.

Conclusion

Osteoporosis results in fragile bone through negative bone remodeling. As such, prior to performing spinal fusion on osteoporotic patients, surgeons should consider multidisciplinary strategies including the use of the anti-resorptive and anabolic agents, proper instrumentations, and BMA. Perioperative strategies in osteoporotic patients may affect the radiological and clinical outcomes.

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Dr. Field is a board certified, fellowship trained orthopedic spine surgeon at Desert Institute for Spine Care. Dr. Field has specialized training in minimally invasive spine surgery and motion sparing technologies, such as cervical and lumbar artificial disc replacement and non-fusion stabilization. In addition, he has extensive training in adult deformity correction and treatment. Dr. Field earned his medical degree at Tulane University, where he finished in the top 1% of his class. He completed both his surgical internship and orthopedic surgery residency at Duke University and completed a spine surgery fellowship at The Spine Institute in Santa Monica (CA). Dr. Field was recognized by his peers to be one of the top Phoenix spine surgeons in 2009, 2011, 2012 and 2013. He was also recognized as one of *America's Most Compassionate Doctors*.

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Spinal Research Foundation Research Partners

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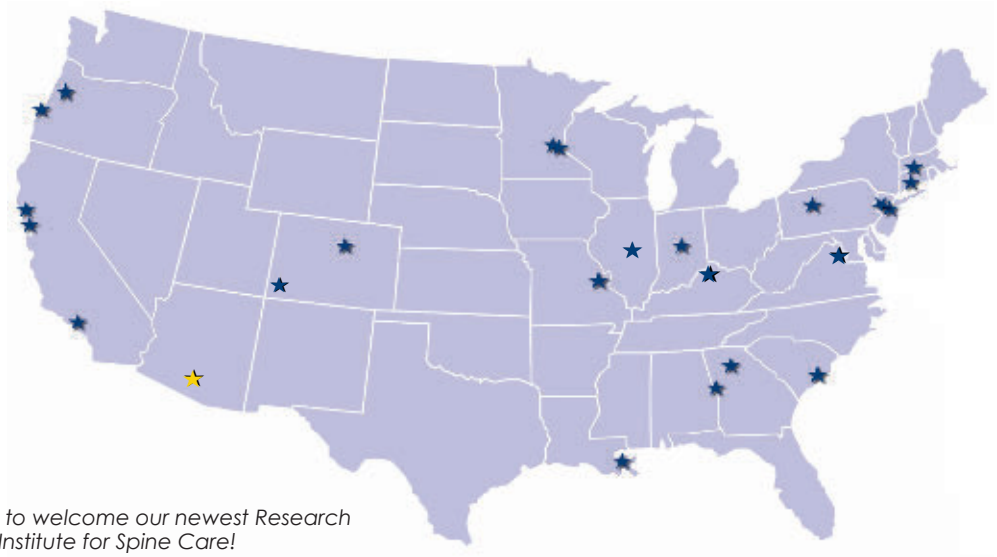

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