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What's new in spine surgery

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SPECIALTY UPDATE

WHAT'S NEW IN SPINE SURGERY

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What's New in the Treatment of the Cervical Spine

An increasing number of prospective studies have established the efficacy of many cervical spine procedures. At the same time, complications and morbidity have been critically analyzed. Several of these studies regarding anterior fusion and laminoplasty will be reviewed.

Outcomes

Long-term follow-up with use of validated instruments and strict radiographic criteria are effective for evaluating surgical results. The Cervical Spine Research Society prospectively followed 181 patients for two years to assess the influence of plates on outcomes. In patients with single-level fusions, the use of a plate was associated with a significantly higher rate of successful fusion (94% compared with 73%). Rigid and translational plates were associated with better results than plates that only allowed the toggle of screw heads. Other studies of intervertebral fusion devices have demonstrated conflicting results. Carbon fiber-reinforced spacers used as stand-alone devices had results similar to allografts, whereas tantalum mesh implants had poor results that necessitated the discontinuation of a randomized study.

Pulsed electromagnetic field stimulation has been shown to induce fusion in the lumbar spine and the healing of extremity nonunions. In a prospective, randomized study, pulsed electromagnetic field stimulation was associated with higher rates of successful cervical fusion (84% compared with 69%), although no significant differences in functional outcomes were noted. Interestingly, successful fusion, either with or without pulsed electromagnetic field stimulation, was significantly correlated with good clinical outcomes. Controversies still remain with regard to the approach (i.e., anterior or posterior) for treatment of cervical spondylotic myelopathy. In a randomized study comparing corpectomy and autograft

fusion with laminoplasty, no differences were noted with regard to the rate of neurologic recovery or the range of motion of the neck. However, both groups had significant improvement in neurologic function. Axial pain was greater in the laminoplasty group. Complications in the anterior treatment group included dysphagia and pseudarthrosis, whereas those in the laminoplasty group included motor root paralysis and increased kyphotic angulation.

Recombinant human bone morphogenetic protein-2 (rhBMP-2) has been used off-label to promote fusion following anterior cervical discectomy, with fusion rates of 100% having been noted. A recent warning letter from the manufacturer was sent to surgeons, noting that some patients have had development of hematoma and postoperative retropharyngeal swelling with symptoms of dysphagia, hoarseness, and airway obstruction requiring reintubation. The exact etiology is unclear but most likely is related to an inflammatory effect resulting from a high protein dose. The use of fibrin glue to control the spread of BMP may limit its dispersion and has been shown to have a protective effect on the neuroelements from undesired bone formation. Its use for the prevention of the retropharyngeal inflammatory response observed in association with cervical off-label use has not been examined.

Laminoplasty

Laminoplasty has gained in popularity for the treatment of cervical myelopathy secondary to ossification of the posterior longitudinal ligament and spondylosis with spinal stenosis. The major morbidities include C5 motor-root paralysis (in 5% to 10% of patients) and chronic neck pain (in up to 30% of patients). Many etiologies for C5 motor paralysis have been hypothesized, including the suggestion that the C5 root is short, is tethered, and branches at a right angle at the apex of the lordosis and therefore is subjected to greater traction when the spinal cord shifts posteriorly. Another etiology, newly

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identified, is cord rotation. Increasing rotation of the cord in excess of 4° has been significantly associated with postoperative C5 paralysis in comparison with other factors such as the compression ratio or the presence of foraminal stenosis.

During laminoplasty, continuous electromyographic monitoring of the C5 root can identify a deficit early. Positive findings are spontaneous discharges, which can lead to changes in the procedure such as adjustments of arm positioning or alterations in decompressive techniques. Another method is prophylactic bilateral C4-C5 foraminal decompression.

Several techniques to reduce axial neck complaints following laminoplasty have been proposed. These proposed techniques have included preservation of the C7 spinous process, maintenance of the insertion of the semispinalis cervicis insertion into C2, and elimination of bracing and initiation of early range of motion, especially extension.

Morbidity

The anterior cervical approach is occasionally associated with long-term voice disturbances and dysphagia. In the Cervical Spine Research Society outcome study, the incidence of new-onset dysphagia after surgery was 29.8% at three months, 6.9% at six months, and 6.6% at two years. The use of plates resulted in a 1.6-times higher incidence, and higher rates were noted following procedures involving multiple levels and more cephalic levels.

Newer translational plates allow settling in the long axis of the spine after interbody graft resorption and theoretically result in higher fusion rates. Most plate designs use oblong holes, and, as settling occurs, the plate translates toward the next adjacent nonfused level. Plates within 5 mm of nonfused disc spaces have been associated with adjacent-level disc ossification. This phenomenon, when occurring within three months after surgery, is likely to be progressive.

Esophageal perforations occur rarely in anterior spine surgery but can be devastating. If concern arises, the integrity of the esophagus may be tested by esophageal injection of contrast media such as methylene blue. Placement of a Foley catheter cephalad and caudad to the suspected lesion allows increased pressurization and substantially increases the sensitivity of this test.

What's New in Biologic Topics Related to the Spine

Biologic tools for reconstruction and regeneration continue to be one of the most researched areas related to the spine today. There is a continued effort to enhance the process of achieving spine fusion. With the United States Food and Drug Administration's postmarketing approval of rhBMP-2 in 2002 and its Humanitarian Device Exemption for rhBMP-7 late in 2004, the era of using recombinant bone morphogenetic proteins to achieve spine fusion is here. In fact, some would argue that the limited number of available bone-growth factors has resulted

in increased efforts to promote motion-sparing technologies. There continues to be increased activity related to the development of lower-cost bone-graft substitutes as well. Finally, an increasing amount of research continues to be focused on understanding the biology of the intervertebral disc and developing biologic strategies to retard or reverse degeneration.

Recombinant Osteoinductive Proteins

Since the Food and Drug Administration granted postmarketing approval for the use of rhBMP-2 inside an anterior spine fusion cage, rhBMP-2 on an absorbable collagen sponge carrier has been used by surgeons in closely related applications. In the last year, very high rates of successful fusion (>95%) have been reported when rhBMP-2 has been used for transforaminal lumbar interbody fusion in conjunction with a poly (L-lactide-co-D,L-lactide) bioresorbable spacer or a nonresorbable cage. In addition, rhBMP-2 was associated with a fusion rate of 100% in a study of twenty patients who were managed with anterior cervical interbody fusion in conjunction with a bioresorbable spacer.

There have been sporadic reports of transient postoperative edema and/or swelling in the anterior cervical area, which may be associated with rhBMP-2 when used in high doses. Since use in the anterior cervical spine is not a currently approved marketing label for rhBMP-2, extensive safety data related to this use are not available and therefore surgeons are reminded to exercise caution and to be aware of the potential perioperative risks. A second complication resulting from BMP was reported in association with the use of stand-alone titanium fusion cages for posterior lumbar interbody fusion. A two-year multicenter pilot study demonstrated that several patients had posterior overgrowth of bone into the spinal canal, most likely because of inadequate countersinking of the metal cage. The patients with bone overgrowth did not report worse clinical outcomes, and the rate of successful fusion was 93%.

One-year results were reported following the use of rhBMP-7 as a replacement for iliac crest autograft in patients managed with posterolateral lumbar arthrodesis for the treatment of degenerative spondylolisthesis. That prospective, randomized, controlled, multicenter clinical study involved radiographic follow-up of twenty-nine of thirty-five patients and demonstrated a 74% rate of successful fusion in the BMP-7 group as determined on the basis of plain radiographs. The fusion rate in the autograft control group was similar (60%). There was no significant difference between the rhBMP-7 group and the autograft group with regard to clinical outcomes as determined with Oswestry and SF-36 pain index scores.

The United States Food and Drug Administration granted a Humanitarian Device Exemption authorizing the use of rhBMP-7 for the treatment of established posterolateral spine pseudarthrosis when the use of bone marrow or iliac crest bone is not possible. The Humanitarian Device Exemption approval establishes the safety of a device but clearly states

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that its effectiveness has not been demonstrated. This is a relatively new approval mechanism that surgeons should be sure that they understand. The Humanitarian Device Exemption approval process requires the hospital institutional review board to approve the use of the device for the specific indication authorized by the Humanitarian Device Exemption. Since the institutional review board protocol specifies the use authorized by the Humanitarian Device Exemption, off-label use is not permitted by the institutional review board as it would be a violation of the protocol. The Humanitarian Device Exemption device still must be treated as an experimental device from the standpoint of the institutional review board. Surgeons and appropriate hospital committees should familiarize themselves with these rules in detail. Although there are no published data on the use of rhBMP-7 for the treatment of posterolateral pseudarthrosis in humans, a study on the treatment of nonunions in rabbits demonstrated that the rate of successful fusion associated with rhBMP-7 (82%) was superior to that associated with autograft (42%). The dose was identical to that recommended for human use and is somewhat lower than doses typically required for consistent bone induction by other BMPs in primates. In another study, which involved three-level posterolateral uninstrumented fusion in a sheep model, rhBMP-7 demonstrated no improvement with regard to healing compared with autograft. That mechanically challenging model emphasized the point that even potent osteoinductive proteins cannot independently overcome an unstable mechanical environment.

A third osteogenic protein, known as Growth and Differentiation Factor-5 (GDF-5), is also being tested for spine fusion applications. This protein recently was reported to generate successful endoscopic posterolateral spine fusions in sheep and currently is under investigation in human clinical trials.

Other Bone-Graft Substitutes

Given the relatively high cost of recombinant BMPs, a variety of other bone-promoting strategies continue to be investigated. Demineralized bone matrix (DBM), which contains natural BMPs (if properly processed), continues to be used in clinical practice. A common misconception is that all DBMs are the same. In a recent study from the University of California at Los Angeles, a rat spine fusion model was used to demonstrate a stark difference between three brands, ranging from no activity (Allomatrix), to inconsistent activity (DBX), to consistent fusion (Grafton). As the study involved immune-deficient rats, human bone taken from product inventory in an operating room was used. Since last year, two additional published studies (one human study and one pig study) have failed to show any enhancement of bone-healing in association with the use of platelet gel concentrates.

Biologic Treatments for Disc Degeneration

Disc degeneration remains an endemic reality of aging. As is

the case with most conditions, there is likely to be some genetic predisposition. A study from Finland added support to earlier studies linking vitamin D polymorphisms to disc disease and proposed a possible association between interleukin-1 gene polymorphisms and low-back pain. That study was unique in that it correlated the genetic findings with a clinical symptom rather than a radiographic observation. Another study demonstrated smoking-induced chondrocyte metabolic changes, including increased levels of interleukin-1 beta, in a rat model.

There has been continued interest in studying the effects of BMPs on disc chondrocyte function. Studies from Atlanta have demonstrated similar results with BMP-2 increasing aggrecan, collagen type II, TGF-beta, and BMP-7 mRNA just as have been reported for some time with BMP-7 and TGF-beta. As further evidence of the attention that this field is receiving, the 2004 International Society for the Study of the Lumbar Spine prize was awarded to a paper demonstrating the ability of the intracellular regulatory protein, LMP-1, to upregulate intervertebral disc cell production of proteoglycans and multiple BMPs in vitro and in vivo. Thus, several groups have demonstrated some short-term responses to BMPs and now LMP in the intervertebral disc, but the key issues are whether or not any of these strategies can work in primates, whether they can retard or reverse disc degeneration, and what the duration of any beneficial effect may be.

What's New in Spinal Deformity Surgery

The definition and scope of spinal deformity continues to evolve. Certainly, the term spinal deformity includes conditions such as idiopathic adolescent scoliosis, congenital scoliosis, posttraumatic deformities, and adult spinal deformities. Motion preservation and spondylolisthesis are considered by the Scoliosis Research Society to be within the realm of spinal deformity.

Genetics

Work continues to evolve on the genetic etiology of idiopathic scoliosis. It appears that the pathogenesis of idiopathic scoliosis is complex and is affected by both genetic and environmental factors. There are also data from Denmark suggesting that there is a substantial genetic component to Scheuermann kyphosis.

Etiology and Natural History of Idiopathic Scoliosis

We still have a long way to go in understanding the etiology of idiopathic scoliosis. Cheung reported that pinealectomy did not result in the development of scoliosis in young nonhuman primates. That study calls into question whether or not melatonin is a factor in primates. Work from Montreal, however, suggests that melatonin signal transduction is impaired in patients with severe idiopathic scoliosis. This theory was based on primary cell cultures prepared from musculoskeletal tissues from these patients.

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*Surgical Treatment of**Adolescent Idiopathic Scoliosis*

There is still considerable debate about the treatment of thoracic curves. Options include both anterior and posterior treatment and, for larger curves, anterior release. To some extent, the use of thoracic pedicle screws is changing the tide-mark. In many instances, it now appears that anterior release is not necessary if pedicle screw fixation can be utilized. There is still considerable debate about the advantages of using a construct of apical sublaminar wires as opposed to pedicle screws. Both techniques work well. Perhaps of bigger concern is the prevalence of either proximal or distal junctional kyphosis after treatment. The prevalence of junctional kyphosis may be somewhat higher in association with the use of pedicle screws. It certainly appears that the prevalence of junctional kyphosis is greater in association with the use of a posterior approach than it is in association with the use of an anterior approach. It appears that anterior treatment provides a more reliable correction of the hypokyphotic thoracic spine than posterior instrumentation does. On balance, it appears that there is still a role for anterior and posterior treatment as well as for hooks, apical sublaminar wires, and pedicle screws. One particular technique is not clearly superior to another.

Adult Spinal Deformity

The surgical treatment of adult spinal deformity remains one of the biggest challenges in spinal deformity surgery. There is a role for Smith-Petersen osteotomy, pedicle subtraction procedures, and posterior vertebral column resection for the treatment of sagittal and coronal fixed imbalance. With long fusions to the sacrum, protection of the sacral screws by means of both anterior column support and pelvic fixation (iliac screws) has many advantages but does not completely eliminate the risk of pseudarthrosis. It is possible to harvest iliac bone if the surgeon stays at least 1 cm away from the iliac screws without running the risk of loosening these screws. A clinical outcomes assessment of patients with adult scoliosis indicated that a markedly positive sagittal balance is the most disabling component of adult spinal deformity. Of the various adult scoliosis curve patterns, those with lower curve apices and diminished lumbar lordosis are the most problematic, irrespective of the coronal curve magnitude.

Congenital Scoliosis

Progress in the recognition, evaluation, and treatment of thoracic insufficiency syndrome continues. Thoracic insufficiency syndrome is a rare condition that represents the pathologic situation in which postnatal lung tissue growth is inhibited by chest cavities with suboptimal volumetric characteristics. The treatment of this condition focuses on the chest wall deformity as opposed to the spinal deformity. Chest wall expansion with use of the VEPTR (Vertical Expandable Prosthetic Titanium Rib) procedure has been advanced as a method of altering the natural history of thoracic

insufficiency syndrome. This procedure is utilized for small children and requires lengthening of the device at six-month intervals. The complication rates are high and are in keeping with those encountered in patients undergoing growing spinal rod procedures. One study that was presented at the annual Scoliosis Research Society meeting in Argentina demonstrated 455 adverse events in 154 patients. Seventy-five percent of those events were judged to be moderate or minor, whereas 21% were viewed as serious. Currently, there are no long-term data to support this approach of chest wall expansion as a treatment for thoracic insufficiency syndrome, but study is ongoing.

Surgical Complications

Iatrogenic spinal fracture through vertebrae that have been treated with pedicle screws has recently been recognized. This lesion occurs at the end vertebra and is characterized as a three-column fracture-dislocation. It is most commonly seen at the cephalad end of a thoracic construct in osteoporotic patients. Vertebral translation can occur, and spinal cord injury has been reported. The key to treatment is early recognition, prior to the development of substantial deformity or neurologic sequelae. Surgical salvage is required but is not always satisfactory.

The impact of having vertebral body screws in close proximity to the aorta is still not clear. There is still quite a bit of concern about this, although clinically the number of either acute or delayed aortic perforations by anterior vertebral body screws appears to be extremely low.

Spinal Biomechanics

On the basis of the work by Roussouly et al., we now know that the C7 plumb line and the center-of-gravity line are not identical. We know that sagittal imbalance is quite disabling; however, we still struggle somewhat with deciding what degree of surgical correction will produce "ideal balance." We need to learn more about the center of gravity and also about the compensatory mechanisms that occur below the spine (e.g., hip extension, knee flexion, and ankle dorsiflexion) to understand factors that determine sagittal balance and to understand the potential remedies for imbalance.

Motion Preservation

The Scoliosis Research Society remains quite interested in motion preservation and the use of disc arthroplasty. One of the lumbar disc arthroplasty devices has now been approved by the Food and Drug Administration. Acceptable results have been reported after two to five years of follow-up. Concerns still exist about the long-term durability of the devices as well as about the options for revision, especially at L4-L5. At this level, any interbody device will be in close proximity to the iliac veins, and, therefore, revision has the potential for catastrophic complications. Range of motion does seem to be pre-

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served following disc arthroplasty, and the prevalence of heterotopic ossification is low.

Spondylolisthesis

There continues to be a trend toward reduction and circumferential fusion rather than fusion in situ for the treatment of high-grade dysplastic spondylolisthesis. However, reduction is associated with a higher prevalence of L5 root deficits. These deficits usually resolve with time. Efforts are being made to understand the factors that differentiate between nonprogressive lytic nondysplastic spondylolisthesis and lytic highly dysplastic progressive high-grade spondylolisthesis. These factors include dysplasia of the posterior elements and changes in the sacral dome and the growth plate of the proximal part of the sacrum. Pelvic incidence (the sum of sacral slope and pelvic tilt) also may be a factor in the development and progression of spondylolisthesis.

What's New in Spinal Cord Injury

The tragic death of Christopher Reeve in 2004 brought to the forefront of public attention the ongoing challenges faced by individuals suffering from paralysis due to spinal cord injuries and served as a harsh reminder of the desperate need for therapies for this devastating injury. Experimental therapies designed to provide neuroprotection and possibly also axonal regeneration, which were once almost the exclusive domain of basic science researchers, are now emerging from the bench as potential candidates for clinical trials focusing on the treatment of spinal cord injury in humans.

Pharmacologic Agents

Recent reports from the neurobiology community have demonstrated encouraging progress in the study of pharmacologic agents that appear to have substantial neuroprotective properties but are also already in clinical use for other, unrelated applications. This obviously has important implications for surgeons because the long-established safety and tolerance of such drugs in humans certainly would facilitate their entry into clinical trials on the treatment of spinal cord injury. The drugs that have generated such interest include erythropoietin, minocycline, and atorvastatin. Independent laboratories have reported that erythropoietin has demonstrated beneficial effects in animal models of acute spinal cord injury, and a great deal has been learned recently about the unique mechanisms, unrelated to its hemopoietic effects, by which this erythropoietic hormone confers tissue protection. Four independent laboratories have demonstrated the neuroprotective effects of minocycline (including tissue protection, diminished cell death, and improved functional outcome) in animal models of acute spinal cord injury. The neuroprotective effects of minocycline were first reported in cerebral injury models and recently were introduced into human clinical studies on the basis of the encouraging results noted in animal models of spinal cord injury. Atorvastatin (more commonly known as

Lipitor) and the other statins that are in use as cholesterol-lowering agents also have been found to have important anti-inflammatory properties and thus have been applied in various animal models of stroke, Alzheimer disease, and, most recently, spinal cord injury. A recent animal study demonstrated that atorvastatin reduced tissue damage at and around the site of spinal cord injury and also promoted motor recovery. Unfortunately, in that study, the atorvastatin was given one week before the injury, and additional results with this drug in a more clinically applicable model are anxiously awaited. In any event, the promising results of these preclinical animal studies and the long-established human safety of these drugs have prompted great interest in initiating clinical trials.

Cellular Transplantation

In the case of orthopaedic surgeons, an interest in cellular transplantation strategies that might promote functional recovery after spinal cord injury is only natural, for the very practical reason that our involvement might be necessary for their application. The experience with cell transplantation for the treatment of acute and chronic spinal cord injury is increasing around the world, and, in an attempt to provide an international forum for the open discussion of these therapies, the International Campaign for the Cure of Paralysis hosted the Clinical Trials workshop in Vancouver, British Columbia, in February 2004. Scientists and clinicians from around the world discussed their experience with human transplantation treatments with olfactory ensheathing cells, peripheral nerve grafts, and autologous activated macrophages. Much excitement around the use of olfactory ensheathing cells has led investigators in Lisbon, Portugal; Beijing, China; and Brisbane, Australia to initiate transplantation trials in humans.

In cord transection studies in animals, Schwann cells derived from bone marrow stromal cells transplanted to the injury zone resulted in substantially greater distal motor recovery. Similarly, olfactory ensheathing cells, which have a unique capacity of growing from the central nervous system to the peripheral nervous system, also have been shown to promote recovery.

Granulocyte macrophage-colony stimulating factor (GM-CSF) is a hematopoietic cytokine that activates stem cells and prevents apoptosis of leukocytes. Similar apoptotic pathways occur in both neuronal and hematopoietic systems. Therefore, GM-CSF may have an effect in spinal cord injuries. In a rat model, GM-CSF was found to be neuroprotective and to prevent neuronal apoptosis. In another study, transplantation of bone marrow cells stimulated by GM-CSF was shown to improve neurologic recovery in animals.

It is important for us as surgeons to have some awareness that these trials are ongoing because one can be quite assured that our patients, with their access to the Internet, are becoming increasingly informed about them. At this moment, peer-reviewed reporting of these trials is unavailable.

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Use of Methylprednisolone

While the current evaluation of these novel technologies is generating much excitement and hope within the spinal cord injury field, the ongoing debate regarding the acute administration of methylprednisolone is closer to the front-line physician who is treating spinal cord injuries. After the initial criticisms directed at the methodology and interpretation of the National Acute Spinal Cord Injury Study (NASCIS) 2 and 3 trials, critical reviews of the use of methylprednisolone have been conducted by the American Association of Neurologic Surgeons, the Congress of Neurologic Surgeons, the Canadian Spine Society, and the Canadian Neurologic Society. All have come to the conclusion that methylprednisolone should not be considered a part of the clinical or medicolegal standard of care for patients with acute spinal cord injuries, but rather that it should be a treatment option only. An interesting study from the Miami Project, which highlighted the potential hazards of methylprednisolone, was published in 2004. The authors performed muscle biopsies during spinal stabilization and subsequent electromyography on five acutely injured patients who received the NASCIS 2 methylprednisolone regime and three patients who did not. Four of the five patients who received methylprednisolone had evidence of acute steroid myopathy and also had corresponding functional changes on electromyography. All three patients who did not receive steroids had normal findings on muscle biopsy and on electromyography.

Clearly, the spinal cord injury field has entered an exciting time in which new therapies directed at the treatment of neurologic injury are entering into clinical trials.

What's New in the Treatment of the Lumbar Spine

Degenerative disorders of the lumbar spine continue to be some of the most common clinical problems that patients face today, and they account for a large percentage of time lost from work in the general population. Accordingly, novel approaches for the treatment of these degenerative conditions continue to represent some of the most impressive technological advances seen in any medical field. The quest for new technology and improvements of commonly accepted treatments are among the most exciting areas of spinal surgery.

Lumbar Disc Arthroplasty

The use of total disc arthroplasty as a motion-preserving procedure continues to be a potentially exciting treatment for lumbar spine disorders. Blumenthal et al., in a two-year follow-up study of 304 patients from fifteen centers who had been enrolled in a Food and Drug Administration trial in which fusion was compared with lumbar disc arthroplasty for the treatment of single-level lumbar disease, reported greater improvement in visual analog scale pain scores for the arthroplasty group at all follow-up times except for twenty-four months.

Zigler et al., in a twelve to twenty-four-month follow-up study in which circumferential fusion was compared with disc arthroplasty performed with use of a different implant, reported that the patients managed with disc arthroplasty had a shorter operative time, less blood loss, and a shorter hospital stay. Clinical outcomes were comparable between the two groups, with the arthroplasty group demonstrating superior outcomes at some of the follow-up time-points.

The relationship between motion after disc arthroplasty and clinical outcome was examined by a group of investigators from The Hospital for Special Surgery. Huang et al., in a study of thirty-eight patients from European centers who were assessed at a mean of 8.6 years after lumbar disc arthroplasty at one or two levels, reported significant associations between the range of motion of the segments and an improved clinical outcome. However, the long-term results of disc arthroplasty need to be compared with those of fusion.

Biological Promoters of Fusion

BMP-2 is known to induce spinal fusion in certain spinal applications. The use of BMP-2 with allograft bone for anterior spinal fusion was examined to evaluate the amount of incorporation of the allograft bone. Burkus et al., in a multicenter study of 131 patients who underwent interbody fusion with use of allograft dowels combined with either BMP-2 (seventy-nine patients) or autogenous bone graft (fifty-two patients), reported increased bone formation and higher percentages of complete allograft incorporation in the BMP-2 group. However, there is a concern that the use of BMP-2 with allograft materials may allow for aggressive allograft resorption, resulting in undesired weakening of the graft and the potential for adverse effects on the structural integrity of the graft and, ultimately, for the spinal fusion. This issue certainly will need to be better defined with future studies.

The issue of cost associated with the use of spinal implants and graft substitutes was examined in a study by researchers in Durango, Colorado, in which iliac crest bone graft was compared with allograft composite with bone marrow concentrate. Specifically, Youssef et al. assessed the hospital costs associated with the harvesting of autogenous iliac crest bone graft as well as the decreased time needed when using the graft composite and found that the overall effect was cost-neutral. This is an important factor to consider when evaluating novel bone-graft substitutes and determining whether the benefits of these substitutes can be measured in terms of cost-savings in addition to the potential benefits that they provide to patients by obviating the need for autogenous bone-grafting.

Surgical Complications

The prevention of surgical complications is always an important issue, and identifying risk factors for these problems is a top priority. Nepple et al., in a study based on a cohort of 2245 patients from one major medical center, reported that

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diabetes, the use of two resident surgeons, the use of red blood-cell transfusions, and obesity were all independent risk factors for surgical wound infections following spinal surgery.

Ahn et al., in a presentation based on a series of 1867 patients who had been enrolled in a multicenter study evaluating predisposing factors for intraoperative dural tears, reported that dural tears during surgery were significantly more common in patients who smoked, had diabetes, or had had an excessive number of epidural steroid injections (more than three during the six months before surgery). Patients who had a combination of these risk factors exhibited a markedly increased risk of intraoperative dural tears, indicating that surgeons should exhibit caution when treating these patients in particular.

Although resorbable implants remain a novel and potentially exciting concept, Herceg et al. noted rapid subsidence in their report on thirty-five lumbar levels that had been treated with circumferential fusion with use of a resorbable anterior ring device combined with BMP-2 and posterior pedicle screws. At six months, 40% of the devices had subsided ≤ 6 mm, 40% had subsided 7 to 9 mm, and 20% had subsided >10 mm. The fusion rate was 88%, and clinical outcomes were good; however, the rapid subsidence led to subsequent surgery in two patients and to collapse and alterations in pedicle screw alignment in several others.

Jenis et al. reported on the complication of symptomatic radiculopathy due to malpositioned pedicle screws. In their report on 838 patients, twenty-one had postoperative radiculopathy due to malpositioned screws. The overall prevalence of this complication was 0.48%; however, no correlation was identified between the clinical outcome and the use of conservative treatment prior to removal, the involved nerve level, or the duration until onset of symptoms. Substantial improvement was noted when screw removal was performed less than sixty days after the onset of symptoms; however, there was greater improvement when removal was performed less than fourteen days after the onset of symptoms. The patients with the most recovery were those who had screw removal less than twenty-one days after the index procedure, regardless of the time of onset of the symptoms.

Patient Satisfaction

When treating patients, surgeons desire good outcomes with high rates of patient satisfaction. Carragee et al., in a prospective study of 168 consecutive patients undergoing lumbar decompression surgery, reported that patient expectations and satisfaction were complex variables. Patients with spinal stenosis expected less from surgery and were satisfied when these lower expectations were met. However, patients with herniated discs expected very good outcomes with regard to function and pain and were dissatisfied if these expectations were not achieved.

Evidence-Based Orthopaedics

The editorial staff of *The Journal* reviewed a large number of recently published research studies related to the musculoskeletal system that received a Level of Evidence grade of I. Over 100 medical journals were reviewed to identify these articles, which all have high-quality study design. In addition to articles published previously in this journal or cited already in this update, seventeen level-I articles were identified that are relevant to spine surgery. A list of those titles is appended to this review after the standard bibliography. We have provided a brief commentary about each of the articles to help guide your further reading, in an evidence-based fashion, in this subspecialty area.

Upcoming Meetings and Events Related to Spine Surgery

The twentieth annual meeting of the North American Spine Society (NASS) will be held on September 27 through October 1, 2005, at the Pennsylvania Convention Center in Philadelphia, Pennsylvania. Web site: www.spine.org.

The fortieth annual meeting of the Scoliosis Research Society (SRS) will be held on October 27 through 30, 2005, at the Loews Miami Beach Hotel in Miami, Florida. It will be preceded by two one-day courses on Adult Spinal Deformity and The Immature Spine, to be held on October 26, 2005. Web site: www.srs.org.

The thirty-third annual meeting of the Cervical Spine Research Society (CSRS) will be held on December 1 through 3, 2005, at the Manchester Grand Hyatt in San Diego, California. The twenty-second annual meeting of the CSRS European Section will be held on May 17 through 20, 2006, in Berlin, Germany. Web site: www.csrs.org.

The Federation of Spine Associations will present the spine program at Specialty Day at the Annual Meeting of the American Academy of Orthopaedic Surgeons, to be held on March 11, 2006, in New Orleans, Louisiana. Web site: www.aaos.org.

The annual meeting of the International Society for the Study of the Lumbar Spine (ISSLS) will be held on June 13 through 17, 2006, in Bergen, Norway. Web site: www.issls.org.

The thirteenth annual International Meeting on Advanced Spine Techniques (IMAST) will be held on July 12 through 16, 2006, in Athens, Greece. Web site: www.imastonline.com.

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Evidence-Based Articles Related to Spine Surgery

Assendelft WJ, Morton SC, Yu EI, Suttrop MJ, Shekelle PG. Spinal manipula-tive therapy for low back pain. *Cochrane Database Syst Rev*. 2004;1:CD000447.

This study was a meta-analysis of fifty-three articles on thirty-nine randomized, controlled trials evaluating the effectiveness of spinal manipula-tive therapy for the treatment of low-back pain. The conclusion of the study was that there is no evidence that spinal manipulative therapy is superior to other standard treatments (physical therapy, analgesics, exercises, back school, or general practitioner care) for patients with acute or chronic low-back pain.

Brown EM, Pople IK, de Louvois J, Hedges A, Bayston R, Eisenstein SM, Lees P; British Society for Antimicrobial Chemotherapy Working Party on Neuro-surgical Infections. Spine update: prevention of postoperative infection in patients undergoing spinal surgery. *Spine*. 2004;29:938-45.

This study was a review of prophylactic antibiotic treatment for the prevention of wound infection. A positive effect was found in all six random-ized, controlled studies cited. On the basis of this review, the authors recom-mended cephalosporins for patients undergoing routine spinal surgery and recommended a combination of glycopeptide and gentamicin for those who are known carriers of methicillin-resistant staphylococcus aureus and those who are at risk for infection.

WHAT'S NEW IN SPINE SURGERY

Brown MD, Brookfield KE. A randomized study of closed wound suction drainage for extensive lumbar spine surgery. *Spine.* 2004;29:1066-8.

This was a prospective, randomized study of the risks and benefits associated with the use of closed suction drainage for patients undergoing extensive lumbar spine surgery. The authors reported no significant differences between patients with a drain and those without a drain with regard to infections, epidural hematomas, or new neurological deficits, and they concluded that drainage usage should be used at the discretion of the operating surgeon.

Buhrman M, Faltenhag S, Strom L, Andersson G. Controlled trial of Internet-based treatment with telephone support for chronic back pain. *Pain.* 2004; 111:368-77.

This was a prospective, randomized trial in which a group of patients who were managed with an Internet-based pain-management program with telephone support (the treatment group) were compared with a group of patients who received no treatment (the control group). Although both groups demonstrated some improvement, the treatment group demonstrated significant improvement with regard to control over pain and the ability to decrease pain.

Buttermann GR. Treatment of lumbar disc herniation: epidural steroid injection compared with discectomy. A prospective, randomized study. *J Bone Joint Surg Am.* 2004;86:670-9.

This was a very well-done study that compared the results of epidural steroid injection with those of surgical discectomy for the treatment of lumbar disc herniation. The study strongly suggested that if a patient is not improving with tincture of time, the first step should be an epidural steroid injection and, if that does not alleviate the symptoms, then consideration should be given to surgical discectomy. This, of course, assumes no contraindication to a steroid injection and no substantial neurologic deficit.

Dey D, Simpson CW, Collins SI, Hodgson G, Dowrick CF, Simson AJ, Rose MJ. Implementation of RCGP guidelines for acute low back pain: a cluster randomized controlled trial. *Br J Gen Pract.* 2004;54:33-7.

This was an investigation of the impact of outreach visits to promote clinical guidelines for the treatment of low-back pain among primary-care teams in Northwest England. The adoption of clinical guidelines was not significantly enhanced by systematic outreach intervention as a result of primary care physician referral to more expensive modalities such as specialist intervention and pain clinic management in patients with persistent complaints of low-back pain.

Fritzell P, Hagg O, Johnsson D, Nordwall A; Swedish Lumbar Spine Study Group. Cost-effectiveness of lumbar fusion in nonsurgical treatment for chronic low back pain in the Swedish Lumbar Spine Study: a multicenter, randomized, controlled trial from the Swedish Lumbar Spine Study Group. *Spine.* 2004;29:421-34, Z3.

Surgical fusion resulted in higher societal total costs and higher costs per patient for the health-care center than nonsurgical intervention did. However, treatment outcomes were significantly better in the surgical fusion group.

Gross AR, Hoving JL, Haines TA, Goldsmith CH, Kay T, Aker P, Bronfort G; Cervical Overview Group. A Cochrane review of manipulation and mobilization for mechanical neck disorders. *Spine.* 2004;29:1541-8.

This was a systematic review of thirty-three randomized, controlled studies comparing various forms of manipulation and mobilization for the treatment of neck pain disorders. The authors found no evidence to support the use of manipulation or mobilization alone but reported that these modalities appeared to be effective when combined with an active exercise program. The conclusions of the study were very limited because of inconsistent diagnoses and the lack of control with regard to how mobilization and manipulation were performed.

Gross DP, Battie MC, Cassidy JD. The prognostic value of functional capacity evaluation in patients with chronic low back pain: part I: timely return to work. *Spine.* 2004;29:914-9.

This historical cohort study evaluated the validity of a functional capacity work systems evaluation in predicting return to work among 150 patients with low-back injury who were managed at a major Canadian rehabilitation center. The results of the functional capacity evaluation were only weakly associated with time to benefit suspension and return to work and explained only approximately 10% of the variations in outcome when associated variables were considered.

He D, Veierstedt KB, Hostmark AT, Medbo JL. Effect of acupuncture treatment on chronic neck and shoulder pain in sedentary female workers: a 6-month and 3-year follow-up study. *Pain.* 2004;109:299-307.

This was a well-done randomized, controlled study in which acupuncture was compared with sham acupuncture for the treatment of chronic, non-disabling headache, neck pain, and shoulder pain in twenty-four office workers. The results at six months and three years demonstrated better pain relief, reduced headaches, and diminished muscle spasms in association with acupuncture.

Hurley DA, McDonough SM, Dempster M, Moore AP, Baxter GD. A randomized clinical trial of manipulative therapy and interferential therapy for acute low back pain. *Spine.* 2004;29:2207-16.

This was a prospective, randomized trial that compared the use of manipulative therapy, interferential therapy, and a combination of both for the treatment of acute low-back pain. All patients were given a book of treatment information. The authors concluded that there was no difference between the effects of a combined program of manipulative therapy and interferential therapy and either manipulative therapy or interferential therapy alone.

Karjalainen K, Malmivaara A, Mutanen P, Roine R, Hurri H, Pohjolainen T. Mini-intervention for subacute low back pain: two-year follow-up and modifiers of effectiveness. *Spine.* 2004;29:1069-76.

This was a prospective, randomized trial in which two types of mini-intervention were compared with standard-of-care treatment for patients with subacute disabling low-back pain. Although the implementation of the mini-interventions (examinations, educational sessions, and careful explanations of the typical course of low-back pain, with or without a worksite visit) did not have a significant effect on the intensity of the pain or perceived disability, the interventions did reduce daily symptoms, costs related to the low-back pain, and absenteeism from work due to pain.

Khot A, Bowditch M, Powell J, Sharp D. The use of intradiscal steroid therapy for lumbar spinal discogenic pain: a randomized controlled trial. *Spine.* 2004;29:833-7.

This was a prospective study in which intradiscal steroid injection was compared with intradiscal placebo injection for the treatment of chronic back pain of discogenic origin. The outcomes in the two groups were identical. Intradiscal steroid injection did not improve the clinical outcome in patients with discogenic back pain and, therefore, appears not to be an advisable procedure.

Liddle SD, Baxter GD, Gracey JH. Exercise and chronic low back pain: what works? *Pain.* 2004;107:176-90. Erratum in: *Pain.* 2004;109:200-1.

This was a systematic review of randomized, controlled studies evaluating the effectiveness of the type and quality of exercise for patients with chronic low-back pain. Overall, patients with chronic low-back pain were positively influenced by a well-supervised exercise program, with the results being maintained in the majority of trials.

Osstelo RW, Goossens ME, de Vet HC, van den Brandt PA. Economical evaluation of a behavioral-graded activity program compared to physical therapy for patients following lumbar disc surgery. *Spine.* 2004;29:615-22.

No significant improvement in outcome measures was noted when

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patients who had received behavioral-graded activity treatment were compared with those who had received normal postoperative physiotherapy. The authors concluded that such behavioral treatment programs are unnecessary following standard lumbar disc surgery because of cost issues.

Turner JA, Loeser JD, Deyo RA, Sanders SB. Spinal cord stimulation for patients with failed back surgery syndrome or complex regional pain syndrome: a systematic review of effectiveness and complications. *Pain*. 2004;108:137-47.

This study was a review of the existing literature regarding the effectiveness of spinal cord stimulation for relieving pain and improving function in patients with failed back surgery syndrome and complex regional pain syndrome. The data were mixed with regard to whether spinal cord stimulation is helpful and effective for this class of patients, and such treatment was associ-

ated with complications and adverse occurrences. This article suggests that spinal cord stimulation is not the answer for this group of patients.

Yelland MJ, Mar C, Pirozzo S, Schoene ML, Vercoe P. Prolotherapy injections for chronic low-back pain. *Cochrane Database Syst Rev*. 2004;2:CD004059.

Prolotherapy is the injection of sclerosing agents, most commonly hypertonic glucose, with the aim of reducing joint instability by strengthening damaged ligaments. This report presented the conflicting results from four randomized, controlled studies on the treatment of low-back pain, two of which showed no positive effect and two of which showed that additional co-interventions had a positive effect. These results were further complicated by the heterogeneity among studies and by the presence of nonstandardized co-interventions.