Spinal Deformity: A Condition that Can Affect All Ages

A Message from Gordon R. Bell, MD
Director, Center for Spine Health

As we headed into the second half of 2009, the Center for Spine Health underwent a change in leadership, but not philosophy.

Under the visionary leadership of my predecessor, Edward C. Benzel, MD, the Center for Spine Health brought together a unique group of individuals consisting of medical spine specialists, interventionists, clinical psychologists, orthopaedic spine surgeons and neurosurgery spine surgeons. The goal and mission of the center has always been to provide the best possible care for patients with spinal disorders. The collaborative nature of this group practice has facilitated patients seeing “the right doctor the first time.” This vision will not change under my own leadership. Fortunately, Dr. Benzel will continue to be a key member of the center as he focuses his time and expertise as Chairman of the Department of Neurological Surgery.

Spinal Column was conceived by Dr. Benzel to help educate the physician community on all aspects of spinal conditions. Each issue has a specific theme and features articles on topics of interest, authored by members of the Center for Spine Health. This Fall 2009 issue of Spinal Column is no exception. This time, we are focusing on spinal deformity, with an emphasis on various types of scoliosis and available treatment options.

Scoliosis is an abnormal (S-shaped) curvature of the spine that affects individuals of all ages and has multiple causes. Idiopathic adolescent scoliosis is the most common type, and is certainly the best known. But scoliosis can have a congenital basis, can occur from neuromuscular conditions or can be associated with age-related degeneration of the spine.

Public awareness of, and school screening for, idiopathic scoliosis have resulted in early recognition and treatment in the United States. Consequently, many potentially problematic curves are identified and treated before they become serious and require major surgery.

There are other types of spinal deformity, however, that are common in the adult population. Some represent a progression of adolescent idiopathic scoliosis. Some occur as a result of the inevitable degenerative changes that occur in all of us; asymmetrical disc degeneration and facet arthritis can cause asymmetric loading of the spine, resulting in a degenerative scoliosis. Other deformities result from prior spinal fusion surgery that may have failed to recreate the normal lordosis in the lumbar spine, sometimes resulting in a flat-back deformity. Fortunately, surgical procedures can address these conditions.

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Nonoperative Care for Patients with Spinal Deformity

By Russell DeMicco, DO

The goals in treating any deformity of the spine are to halt curve progression, minimize pain and maintain function. Treatment is divided into three categories along a continuum of care from least invasive to most invasive: observation, bracing and surgery. The point where care is located along the continuum is impacted by multiple factors, including age, pain, degree of curve, curve pattern, functional limitation, likelihood of continued growth and cosmesis. Thankfully, most deformities of the spine are nonprogressive and, therefore, do not require surgery.

**Observation** typically consists of serial physical examinations and X-rays (36-inch PA and lateral scoliosis series is the study of choice) to evaluate the underlying deformity and any changes from baseline. Small curves are followed during growth and moderate curves (less than 40 to 45 degrees) are followed after growth is complete. The spinal examination should be done the same way each time, with inspection performed from behind while the physician looks for asymmetry in the normal contour or alignment of the spine. Particular note should be made of head carriage and position over pelvis, shoulder blade asymmetry or prominence of rib hump (particularly if worse with flexion), and unevenness of the iliac crests. Exercise and education are important components of treatment during the observation phase of care.

Maintenance of healthy weight, regular exercise and avoidance of smoking should be recommended for all patients, including those with spinal deformity. Patients should be informed that smoking correlates with degenerative changes in the spine and impedes bone healing. Surgeons may not operate until smoking cessation has been maintained for 12 weeks.

The goal of exercise is to minimize any potential decrease in functional ability over time by building strength and flexibility and improving range of motion. An exercise program often begins with prescribed physical therapy, including instruction on posture and body mechanics. From there, the patient may progress to an independent home exercise program, with aerobic conditioning in addition to stretching and strengthening. Regular exercise may improve not only recovery rate should surgery be needed, but a general sense of well-being as well.

**Bracing** is typically used for curves between 25 and 45 degrees in patients who are still growing. The goal of bracing is to prevent further progression of deformity. Different types of braces are available, but they work in the same manner. Most braces are made from rigid plastic and can be worn under clothing. Bracing is usually continued 23 hours per day. A bracing regimen is most successful with early detection of a deformity, mild to moderate curve, compliance with physician examinations, cooperation of patient and support of family, maintenance of a well-fitted brace (including replacement if needed with growth), and continuation of normal activities, including sports.

**Surgery** may be recommended for patients with abnormal spine curves approaching or greater than 45 degrees or associated with pain, functional impairment or severe cosmetic deformity. Curves greater than 40 to 45 degrees tend to progress at the rate of one to two degrees per year. Patients with curves greater than 45 degrees have reported significantly higher pain levels than those with
smaller curves report. Patients treated surgically are more likely to have leg pain, a higher mean level of daily back pain and more frequent moderate-to-severe back pain over the preceding six months. Additionally, significant differences in perceptions of appearance and social function have been shown in surgical vs. non-operative groups.

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Segmental Pedicle Screw Fixation in Fusion for Pediatric and Adolescent Scoliosis

By Ryan C. Goodwin, MD

Significant advances have been made in the surgical treatment of scoliosis in children. Fusion operations, which once were performed without instrumentation and required postoperative casting, have evolved to include segmental spinal fixation with many different types of implants, pedicle screws among them. In some cases, fewer levels need to be instrumented and fused, and postoperative bracing can be eliminated.

Adolescent idiopathic scoliosis (AIS) is the most common spine deformity seen in a pediatric orthopaedic practice (Figure 1). Although many patients can be managed nonsurgically with observation or bracing, surgical treatment is indicated for severe, progressive curves.

Spine fusion remains the gold standard for treating AIS, and is considered when curves reach a magnitude greater than 40 degrees in a growing child and 50 degrees in an adult. Fusion levels are based upon standard PA and lateral scoliosis radiographs. Lateral bending films are also helpful in determining the relative flexibility of a curve, and can help estimate the degree of correction that can reasonably be expected. Computed tomography as well as magnetic resonance imaging can be used in selected cases with severe deformity or other unusual findings.

Pedicle Screw Fixation Now Routine

Pedicle screw fixation was developed in the early 1980s with off-label use in adult low back surgery. Since then, the Food and Drug Administration has approved the implants, and their use is becoming more widespread. Pedicle screws are now used routinely in the thoracic spine for the treatment of spine deformity as well as for trauma and for other applications.

Segmental pedicle screw fixation offers distinct advantages over conventional hook-and-wire constructs. Pedicle screws are significantly stronger biomechanically and have greater strength and correctional power than hooks and wires can provide. The lever-arm obtained with pedicle screw fixation allows for significantly greater strength in achieving rotational correction compared with hooks and wires. Because rotational deformity is a large component of AIS, this technique allows better deformity correction than is possible with conventional constructs.

Surgical Technique

The surgical technique of spine fusion has changed little since its inception. The spine is usually exposed with an incision in the center of the patient’s back. Once the spine is properly exposed, the instrumentation is applied. When all instrumentation has been placed, it is critically evaluated with intraoperative X-ray to ensure proper position. Once instrumentation is complete, the deformity is corrected by placing rods and applying corrective forces. Corrective maneuvers are significantly more powerful with pedicle screws than with hooks and wires.

Once correction has been applied and neurologic indicators are satisfactory, final tightening of the instrumentation to the rods is accomplished and the fusion is completed with the application of bone graft. In many cases, epidural catheters are used to decrease postoperative pain. Just prior to completion of the procedure, two epidural catheters can easily be placed, allowing pain medication to be delivered directly around the spinal canal. Epidural catheters help reduce postoperative pain substantially and decrease the amount of IV pain medication required, thereby decreasing potential side effects of the medication.

The incision is then closed with absorbable sutures just beneath the skin, leaving a cosmetically acceptable scar, with no stitches or staples to remove. Most
patients with idiopathic scoliosis do not require postoperative bracing, although it may be ordered at the surgeon’s discretion. Impact-loading activities, including running and sports, are restricted for six months postoperatively.

Preventing Complications

Potential complications associated with the use of thoracic pedicle screws are similar to those of other spinal implants, and include infection, nerve root or spinal cord injury, vascular injury, bleeding and pneumothorax. Complications can be minimized with safe techniques, the use of intraoperative X-ray and neurologic monitoring. Neurologic monitoring provides the surgeon with real-time feedback on spinal cord function, which helps reduce the rate of neurologic complications.

Although fusion-less surgery for scoliosis is on the horizon, spine fusion remains the standard of care for progressive curves. Spine fusion with pedicle screw fixation offers a safe and powerful means of deformity correction in children and adolescents with scoliosis (Figure 2). Postoperative bracing can be avoided and epidural pain control can be achieved, allowing a less painful recovery and potentially shorter hospital stay. Pedicle screws offer superior strength and correction potential and are becoming the standard of care in many centers for deformity surgery.

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Idiopathic Scoliosis in Adults

By R. Douglas Orr, MD

In the past, it was assumed that once growth stopped, scoliosis would no longer pose a problem to the patient. It has become apparent that scoliosis can continue to affect patients in adulthood, though in different ways. In adolescents, we are concerned primarily with curve magnitude, degree of progression and age of the patient. In adults, we are more concerned about symptoms.

Curves can progress in adulthood. As a general estimate, a thoracic curve greater than 50 degrees or a lumbar curve greater than 40 degrees has a risk of progression in adulthood. The rate of progression averages one degree per year. This does not mean that all curves will progress or that smaller curves will not, but it does explain why we recommend that adults with scoliosis have their curve checked every three to five years. If a curve is progressing, surgery to stabilize it may be recommended.

Medical Management

In most cases, adults with scoliosis require nothing more than periodic monitoring of the spine. These patients have a higher incidence of back pain later in life than those with normal spines have but, in the majority of cases, this pain does not limit activity and is not progressive. One argument in favor of surgery in adolescence has been that it lessens the risk of pain as an adult, but long-term studies have not confirmed this theory. Both the incidence and severity of pain are the same, regardless of whether the patient underwent surgery as an adolescent.

The location of the problematic curve differs in adults and adolescents. In adolescents, the most common concern is a thoracic curve, which is usually the focus of treatment. In adults, it is usually the lumbar curve that causes problems and is the focus of treatment. The reason is that patients with scoliosis, like all adults, develop degenerative changes in the low back with aging. Some have suggested that scoliotics may develop more changes because of the increased and asymmetric loads placed on the disc and facet joints due to the curve. In general, it is age-related degenerative changes that give rise to symptoms in adults with scoliosis.

One often-forgotten area in the management of adults with scoliosis is prevention and treatment of osteoporosis. If osteoporosis develops, a curve can progress through fractures of the vertebrae, which can cause severe pain and deformity. Unfortunately, the osteoporosis can make the bones so weak that there may be no surgical option to treat the pain. Thus, it is vital that older adults with scoliosis be screened for osteoporosis and treated if it develops.

In most cases of scoliosis that require treatment, the presenting complaint is pain: mechanical axial back pain, radiculopathy, stenotic or claudicant leg pain, or pain due to decompensation of the deformity. Treatment is based on the presenting symptom. In many cases, an ongoing trunk stabilization exercise program will be sufficient to control low back pain.

Adults with scoliosis can get disc herniations and, in general, are treated conservatively, in the same manner as patients with disc herniations and normal alignment. Scoliotics who develop symptoms of spinal stenosis are initially treated with the same type of nonoperative care prior to surgery as are other patients with stenosis.

Surgical Intervention

Only when a patient has pain severe and persistent enough to warrant surgery does scoliosis alter treatment. In many cases, conventional surgical decompression procedures cannot be done due to the risk of destabilizing the curve. Decompressions without fusion for stenosis often have a poor outcome, although some newer, less invasive techniques may have a role in treatment. In general, the goal of surgery is to decompress the nerves, restore balance and stabilize the spine, usually through the use of
rods and pedicle screws. Given the magnitude and potential risks of this type of surgery, these operations are done only when patients have symptoms that seriously limit their lifestyle.

In some such cases, the spine “decompensates,” leading to a loss of spinal balance (Figure 1). There is great variation in alignment of the spine, but very little variation in spinal balance. Normal balance occurs when the head is centered over the pelvis in both the AP and lateral planes. A patient who is out of balance must expend more energy to stand and walk, which can result in pain and reduction in function. Once balance has been lost, the deformity will almost inevitably progress. In this situation, surgery to restore balance is the only option (Figure 2). Nonoperative measures cannot correct a decompensated spine. A patient who is unable to stand balanced for even a brief period of time, who has a decompensated deformity and who is symptomatic should be assessed for surgery.

Most adults with scoliosis will never need surgery, and any symptoms they may develop can usually be managed nonoperatively. For those with severe symptoms, or for those unable to stand upright, surgery is a good option, though it is often extensive and carries significant risks. Procedures of this nature should be done at centers with extensive experience in adult deformity surgery.

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Surgical Correction of Adult Scoliosis

By Michael Steinmetz, MD

Adult scoliosis is a spinal deformity in patients who have reached skeletal maturity. Strictly speaking, the condition is defined as a curve in the frontal plane greater than 10 degrees, as determined by measuring the Cobb angle (Figure 1). There are a number of etiologies.

This condition was rarely mentioned in early texts on scoliosis surgery. Moreover, only a few surgeons were operating on the condition. Patients were felt to be too fragile to undergo a large surgical correction, or the bone stock was considered too poor for major corrective surgery. Patients were told they would have to live with the condition.

More recently, the focus has shifted to surgical correction of adult scoliosis. Many advances have occurred in spinal instrumentation, surgical technique, diagnostic tools and anesthesia. In addition, patients have become more medically aware in the Internet era, and are dissatisfied living with functional limitations and pain. In general spine practice today, adult scoliosis is seen much more frequently than childhood or adolescent scoliosis.

Classification

Adult scoliosis can be classified largely into three groups. The first is de novo scoliosis, in which the curve is mainly in the thoracolumbar and lumbar spine. It is due to asymmetric degeneration of one or more discs, asymmetric loading, and translation and rotation of the vertebral bodies. The curve occurs in the frontal plane and is associated with flattening of the lumbar spine in the sagittal plane. This is the classic “degenerative scoliosis” (Figure 1).

The second group is progressive idiopathic scoliosis into adulthood, in which a childhood curve progresses, often from mechanical causes or from bony or degenerative changes. It is the least common among the three groups (Figure 2).

The third group is secondary degenerative scoliosis, which is due to the progressive degeneration of the spine below (most commonly) or above an existing idiopathic scoliosis. This condition may be secondary to pelvic obliquity, limb length inequality or metabolic bone disease. Due to the widespread use of Harrington distraction rods in the 1970s and 1980s, this condition is relatively common (Figure 3).

Symptoms

Back Pain

By far the most common patient complaint is pain that is frequently deep and agonizing, made worse with activity and relieved with rest. The pain is often located in the back, but patients may also have unilateral or bilateral leg pain or a combination of both leg and back pain. The back pain is often located at the apex of the curve, and may be caused by muscular fatigue or true instability. This pain may be worsened by an unbalanced spine.

Neurological Symptoms

Patients may have spinal stenosis and neurogenic claudication from disc degeneration, disc bulging or facet hypertrophy, resulting in narrowing of
the spinal canal. Patients may present with pain, numbness and tingling in the legs that is worse with standing and walking and relieved with sitting. Patients may also have true radicular or unilateral leg pain, most often due to asymmetric facet hypertrophy, disc bulging, and foraminal or lateral recess stenosis. The stenosis and leg pain are often on the concavity of the curve.

Cosmesis
In the adult, cosmetic concerns are often related to postural changes, usually due to imbalance of the curve rather than a rib hump, which is a common concern in adolescent scoliosis. Patients may complain of a fixed forward flexed posture (kyphosis) and inability to stand up straight: the so-called “flat-back syndrome” (Figure 4). They may lean to the side when they ambulate. In severe cases, the ribs may abut the iliac crest, leading to more pain and discomfort. These postural changes worsen with muscle fatigue.

Diagnostic Tools

Imaging
All patients should be evaluated by three-foot standing AP and lateral scoliosis radiographs. The entire curve should be evaluated in both the frontal and sagittal planes, thus allowing the measurement of all curves and the determination of spinal balance. Overall balance is assessed by drawing a plumb line from the midportion of the C7 vertebral body. In the frontal plane, this plumb line should fall in the middle of the sacrum or at least between the S1 pedicles; in the sagittal plane, it should fall roughly through the L5/S1 disc space, preferably through its dorsal aspect. Flexion/extension and lateral bending radiographs should be included as needed to look for any translational instability and to assess the flexibility of curves.

Neurological compression may be evaluated by magnetic resonance imaging (MRI) and/or computed tomography myelogram, but it may be difficult at times to evaluate on MRI, particularly with larger curves. Because the entire spine may not be seen on a single sagittal image, it may appear that there is central canal stenosis when there is not.

Additional Diagnostic Tools
Many other diagnostic tools are available to the clinician. Diagnostic facet blocks and/or provocative discography may aid in determining the location or level of spine pain. Selective nerve blocks and/or
Epidural steroid injections may help localize nerve compression, and may aid in determining the response to decompression.

**Treatment**

Conservative therapy should always be tried first. Core strengthening and rehabilitation should be a key aspect of medical management. Patients often suffer from muscular fatigue due to the coronal and sagittal deformity and imbalance of the thoracolumbar and lumbar spine. Medications such as nonsteroidal anti-inflammatory agents are helpful. A short course of muscle relaxants and/or narcotics may be necessary for severe pain. Newer medications, such as gabapentin, may be helpful for radicular or other nerve-related pain. TRANSforaminal and standard midline epidural steroid injections and facet injections may also be beneficial.

**Extensive Surgery**

The surgical treatment of adult scoliosis must be individualized. In general, there are four indications for surgical intervention: back pain, spinal imbalance, curve progression and neurological deficit.

A patient’s most common complaint is often back pain, but it is the most difficult symptom to evaluate and localize for surgical treatment. The pain must be severe and it must interfere with the patient’s ability to pursue enjoyable activities. If the patient can still engage in favorite hobbies with minimal pain, he or she is not a likely candidate for surgery.

The type of surgery must be based upon symptoms, age and medical comorbidities. If there is curve progression or global imbalance, it is likely that instrumented fusion and correction of the deformity will be required, not necessarily to completely correct the curve, but to attain a solid fusion and a well-balanced spine, both in the coronal and sagittal planes (Figures 5a and 5b). With severe deformities, an osteotomy may be required to correct the imbalance. For patients with only leg pain, a simple foraminal decompression (laminotomy), with or without a limited instrumented fusion, may be all that is needed. For neurogenic claudication and multilevel stenosis with minimal or no back pain, a single-level or multi-level laminectomy and selective instrumented fusion may suffice.

Patients with only mechanical back pain and a thoracolumbar or lumbar scoliotic curve can be difficult to manage. Surgery for such patients involves instrumentation of the primary curve and any secondary curves that do not correct on side bending films. The surgical goal is to achieve a solid fusion and a well-balanced spine. Complete correction of the curve is often neither possible nor necessary. If the patient has neurological symptoms, decompression should be added.
Less Invasive Alternatives

For patients with only leg pain or with minimal back pain, big instrumented fusions may be too much surgery. Many less invasive or less destructive options are now available.

Minimally Invasive Decompression  Tubular minimally invasive approaches are widely used for surgical decompression in patients with leg pain. Very small incisions (few centimeters in length) and arthroscopic approaches to the spine can be used. Generally, both sides of the spine may be decompressed from a single-sided unilateral approach. Due to the small size of the incision and less iatrogenic soft-tissue injury, there is typically less postoperative pain and quicker mobilization following surgery. Outcomes have been similar to those achieved with standard open operations.

Decompression and Selective Fusion  This approach involves removal of one or more facet joints from the back of the spine to decompress one or more nerves. In the scoliotic spine, this may result in instability of the spine and/or curve progression. In these cases, a selected instrumented fusion may be required to permit adequate decompression of the nerves, preventing postoperative instability of the spine (Figure 6). This approach results in quicker recovery and less postoperative pain.

Interspinous Process Distractors  These devices are placed between the spinous processes in the dorsal aspect of the spine (Figure 7). They functionally increase the space available for the nerves and help alleviate leg pain due to lumbar stenosis. These implants are attractive because they may be placed under local anesthesia. Unlike decompression and instrumented fusion, the implants may be inserted without removing tissue such as bone and/or ligament. Fully reversible, they may be removed without permanent change to the spine. If the devices do not adequately relieve leg pain, or if it recurs, they may be removed and a formal laminectomy can be performed. These implants do not appear to result in instability or progression of an adult scoliotic curve.

Expectations

It is imperative that the patient and surgeon have the same postoperative expectations. The patient should understand the specific goal of the operation (e.g., improvement in back pain, leg pain or both). In addition, the patient should know that:

- Recovery time from a large operation may be lengthy (six to 12 months).
- The chance that back pain will substantially improve is only moderate (likelihood of improvement is much better for radicular leg pain and claudication symptoms).
- The risk of complications is directly proportional to the magnitude of the surgery; quicker recovery and less postoperative pain are usually seen with the less invasive operations.

Conclusion

Advances in anesthesia and spinal instrumentation have made scoliosis surgery in adults much safer and more effective. With individualized surgical treatment, good outcomes are now the norm.

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Iatrogenic Spinal Deformity: Prevention and Treatment

By R. Douglas Orr, MD

Iatrogenic deformity is an all-too-common result of spinal surgery. As rates of spinal surgeries (especially lumbar fusions) have increased, so has the incidence of iatrogenic deformity. In some cases, the deformity occurs in spite of appropriate surgical treatment; in many other cases, the deformity could have been prevented with appropriate attention to spinal alignment.

Procedures such as laminectomy are used to decompress nerve roots, and are very effective in the treatment of leg pain due to nerve compression. In patients with a pre-existing scoliosis or spondylolisthesis, however, these procedures can remove stabilizing structures and lead to a progressive deformity. This outcome can often be prevented by doing more minimal decompressive procedures or by fusing segments where potential instability is a concern.

If a deformity occurs, the surgery to correct it is usually much more extensive and carries higher risks. Also, the longer a deformity is allowed to progress, the more difficult it is to correct. When one observes deformity progression after surgery, it is often tempting to just “keep an eye on it,” but this is not a good option in the majority of cases. Once the spine has decompensated, progression is inevitable. The earlier the deformity is addressed, the easier it is to deal with.

The Importance of Alignment

One of the most important aspects of spinal alignment is spinal balance. The body goes to great lengths to ensure that the head remains centered over the pelvis in both the AP and lateral planes. As we age and our discs degenerate, we lose the normal lordosis in our lumbar spine, but remain in balance. A patient who has a fusion in the spine loses the ability to compensate for and correct alignment through the fused portion of the spine.

It was often assumed that for a 1- or 2-level fusion, the alignment was not particularly important because the rest of the spine could compensate. In the short term (one to five years), this is probably true, but may not be so in the long run. A growing body of evidence shows that failure to restore anatomic alignment may increase the risk of further degeneration above a fusion. It is common to see patients with a series of 1-level fusions, each successful on its own, but with degeneration of the adjacent level leading to a second fusion, then a third and so on. If the fusions are done without restoring alignment, then a “flat-back” deformity can occur due to loss of lordosis.

Flat-Back Deformity

Flat-back syndrome presents with a typical constellation of symptoms. Usually, the first symptom is muscular back pain when standing or walking for prolonged periods. This pain is relieved by sitting or by leaning on something, such as a shopping cart or a cane. It is caused by fatigue of the trunk muscles, which are forced to work harder to keep the spine upright. If the deformity progresses, the patient begins to walk with flexed hips and knees to keep the head over the pelvis. This posture leads to pain in the anterior thighs from overexertion of the quadriceps, and further limits standing and walking.

In the early stages of flat back, an exercise program to strengthen the trunk muscles may help increase...
exercise tolerance but, once the deformity is established, surgery is the only option to restore spinal alignment. The surgical options are varied, but they have the common feature of restoring lordosis to the lumbar spine. Which surgical option is selected depends on the severity of the deformity, its location, how many levels were operated upon and how many levels actually achieved successful fusion. In some cases where a proximal level has degenerated, we can use techniques to increase lordosis when we fuse the adjacent level. If a fusion did not heal, then we can mobilize that disc level and get correction through the previously attempted fusion. In some cases, this is done through a combined anterior and posterior surgery.

Spinal Osteotomy

If the deformity is very rigid, then an osteotomy is required to achieve correction (Figures 1 and 2). One type of osteotomy removes the facet joints and then compresses the posterior part of the spine to restore lordosis. In large deformities, a more extensive procedure is performed in which the pedicles and a wedge of the vertebral body are removed. This procedure, called a pedicle subtraction osteotomy, can reliably achieve 30 degrees of correction.

Spinal osteotomies are major surgeries, and are regularly performed at only a small number of centers in this country. They carry high risks, but can produce a very dramatic improvement in quality of life for a patient with a flat-back deformity.

Iatrogenic deformity is an unfortunate but often preventable sequela of spinal surgery. Prevention is the optimal strategy but, when treatment is promptly instituted, it is often less extensive. Major structural deformities are significant surgical challenges, but can result in very good outcomes.

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Clinical Trials

Prospective outcomes evaluation of decompression with or without instrumented fusion for lumbar stenosis with degenerative grade 1 spondylolisthesis
Edward Benzel, MD
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Randomized, controlled trial of DuraGen Plus Adhesion Barrier Matrix to minimize adhesions following lumbar discectomy
Edward Benzel, MD
216.445.5514

An assessment of P-15 bone putty in anterior cervical fusion with instrumentation
Iain Kalfas, MD
216.444.9064

Cervical spondylotic myelopathy study
Edward Benzel, MD
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The effectiveness of physical therapy for patients with lumbar spinal stenosis
Daniel Mazanec, MD
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November 7, 2009

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