Anterior cervical

CORPECTOMY, FUSION, AND STABILIZATION

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Bailey, Badgley, Cloward, Smith, and Robinson pioneered the anterior surgical approach to the cervical spine in the 1940s. Today, it is the most commonly utilized approach for addressing degenerative disease of the cervical spine. The numerous advantages of the anterior approach are (1) direct visualization of anterior pathologic lesions, (2) safety in terms of avoiding the need for direct manipulation of neural elements, and (3) the ability to directly distract across collapsed disk spaces, thereby reducing buckling of the ligamentum flavum, increasing the size of the neuroforamen, and achieving an indirect decompression of nerve roots. Over the years, two principal procedures have emerged for accomplishing these goals: anterior cervical discectomy and interbody fusion (ACDF), and anterior cervical corpectomy with strut grafting. The anterior corpectomy with strut grafting will be further studied in this article.

Anatomy of the cervical spine

In the cervical region, the C1 to C6 vertebrae contain transverse foramina that perforate each transverse process and also contain the vertebral artery en route to the cranium (Figure 1). The vertebral artery enters the cervical spine through the transverse foramen of the C6 vertebral body.

The atlas, or C1, and the axis, or C2, are distinctive cervical vertebrate. The C1 vertebrae has neither a body nor a spinous process but consists instead of two lateral masses and two arches, anterior and posterior. Its superior facets articulate with the occipital condyles, and its inferior facets with the axis, or C2 vertebrae.

The atlas is prone to an axial compression fracture by trauma, also know as a Jefferson fracture. It is also prone to ligamentous laxity and atlantoaxial subluxation. The atlas can be fused to the occiput, termed occipitalization, and is associated with a variety of craniovertebral junction anomalies, including basilar impression and invagination.

Dimensions of the spinal canal in the cervical regions are important. As one proceeds caudally the diameter of the canal narrows. At the foramen magnum, the normal diameter is 26 to 40 mm and is acceptable with an average diameter of 34 mm.[1] A diameter less than 19 mm often leads to neurologic deficits. At the C5-C6 cervical level, an anterior-posterior (AP) diameter less than 12 to 13 mm often is coupled with deficits and is indicative of spinal stenosis. The usual sagittal diameter at the C5-C6 level is 15 to 20 mm.

Cervical disk disease

Epidemiology

Cervical disk disease is usually seen in males between the ages of 30 and 50 who present with a protruded intervertebral disk.[2] However, cervical spondylosis is more common is older adult patients. Degenerative changes in the cervical spine are universal in the elderly age group, and clinical correlation is important.

Pathogenesis

In the patient presenting with cervical disk disease, the disk degeneration leading to referred pain has several causes that should be explored. In older adults, the aging process and water content change within the disk is one cause for pain. Lifestyle events and posture are other important factors when seeing the patient with pain. Another important factor is autoimmune phenomenon when ruling out causes for pain. Genetic factors and cigarette smoking are also very important.

In cervical spondylosis, there are several changes that can occur. Loss of intervertebral disk height results in cord or nerve root impingement. Osteophytes that form at the posterior zygapophyseal joints, neurocentral joints, and margins of the disk are another important cause of spondylosis in the cervical spine. If the spondylosis is left untreated, segmental instability or a kyphotic deformity may result.

Associated symptoms and signs

The most commonly herniated disks in the neck are at the C5-C6 and C6-C7 levels.[3] Laterally herniated disks at the C5-C6 level usually compress the C6 nerve root and produce paresthesis and numbness in their distribution. Pain radiating down the lateral side of the arm and forearm, often into the thumb and index fingers, and numbness of the tip of the thumb or on the dorsum of the hand over the first dorsal interosseous muscle are often seen. There is frequently demonstrable weakness of the biceps muscle, and the biceps and radial reflexes may be diminished or absent.

Herniation of an intervertebral disk at the C6-C7 level usually irritates the C7 nerve root and may produce hyperalgesia down the medial aspect of the forearm to the ring and small finger and numbness of small and medial portion of the ring finger. The triceps muscle receives a large portion of its innervation through the C7 nerve root. It is often weak, a finding that is usually demonstrable if the reflex is depressed or absent.

A herniated disk at the C7-T1 level compresses the C8 nerve root and may be responsible for hyperalgesia in the hypothenar portion of the ring and the fifth digits. Sensory changes extend up the forearm to about the junction of the middle and distal thirds. Hyperalgesia in this distribution is helpful in distinguishing deficits resulting from compression of the C8 nerve root from those resulting from compression of the ulnar nerve at the elbow.

Historical perspective

The anterior approach to the cervical spine dates back to 1928, when Stuckey attempted to remove a chordoma via an anterior approach.[2] Bailey and Badgley subsequently performed an anterior stabilization technique for the treatment of a lytic tumor involving the fourth and fifth cervical vertebrae. This was followed by Robinson and Smith,[2] who in 1955 described anterior discectomy and fusion with an onlay of iliac crest autograft for cervical spondylosis. This technique was similar to that described by Bailey and Badgley in that there was no direct decompression of the nerve root or spinal cord.

This approach was thought to minimize the risk of neurologic complications from manipulation of the nerve roots or spinal cord, decrease the risk of new osteophyte formation, stimulate osteophytes already present to regress because of the stability provided by the fusion, and reduce buckling of the ligamentum flavum and compression of the nerve root by distraction.

Rationale of the anterior approach

Although many modifications in the Robinson-Smith graft technique have been developed, the approach to the cervical spine continues to provide easy access to the anterior spine today. Currently, the anterior approach is widely used for cervical spondylotic myelopathy involving three or fewer levels in patients with neutral or kyphotic sagittal alignment.[4] Variations in grafting and instrumentation are numerous, attempting to improve fusion rates, correct deformity, and reduce complications and morbidity at the operative and graft donor sites. These variations have led to the debate over discectomy with interbody fusion versus corpectomy and strut grafting, allograft versus autograft, and the use of supplemental internal fixation, which will be further explained in this article.

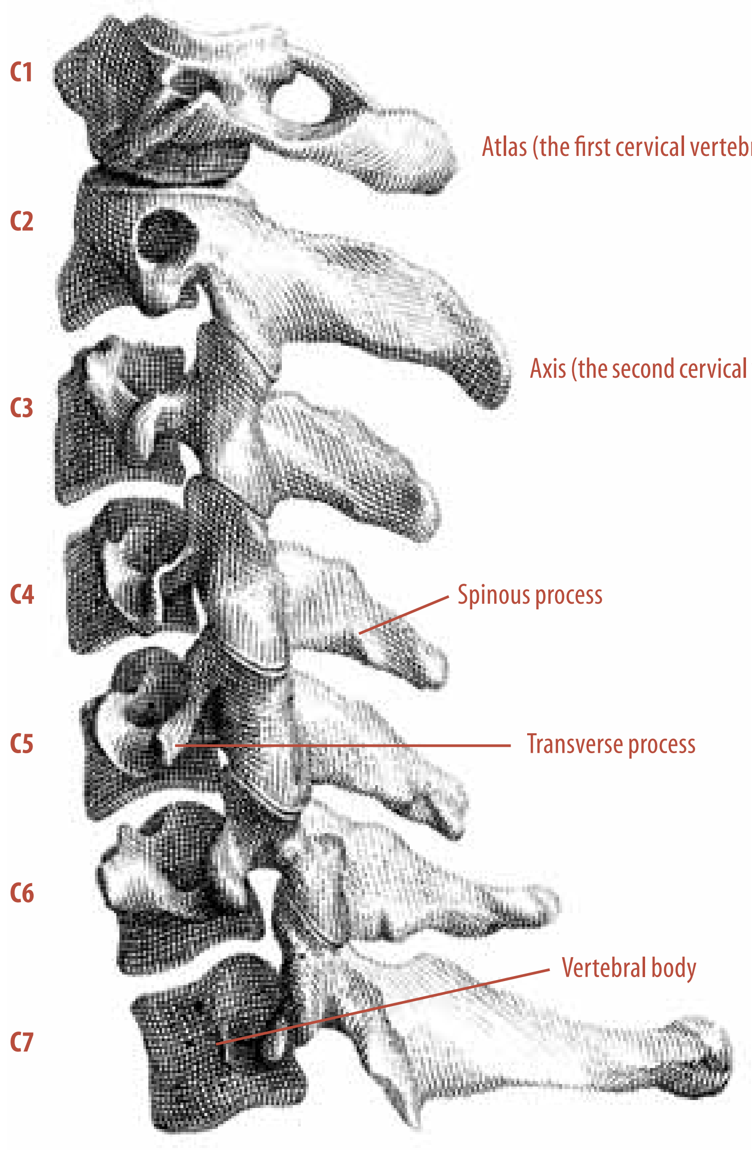

FIGURE 1 Anatomy of the cervical spine.

Rationale of interbody fusion and plates

There is a majority in favor of an anterior cervical discectomy and interbody fusion (ACDF) in patients with cervical spondylotic myelopathy or myeloradiculopathy arising from either a soft disk herniation or osteophytes (hard disk) at a single level.[5,6,7] The addition of instrumentation as an adjunct to ACDF is increasingly being considered the treatment of choice for disease involving one to three cervical segments.[6,8,9]

This is partly because the pseudoarthrosis rate has been shown to be inversely related to the number of fused segments and may be due to increased contact stress at the graft-body inter-

FIGURE 2 Aesculap Caspar plating system.

FIGURE 3 Medtronic Sofamor Danek Orion plating system.

face and the increased number of surfaces over which fusion is expected to occur.

Anterior corpectomy with strut grafting and instrumentation

There are several situations in which anterior corpectomy and strut graft arthrodesis may provide a preferable alternative to ACDF. These include (1) single-level spondylotic myelopathy in which compression is occurring principally posterior to the vertebral body; (2) multilevel spondylosis involving three intervertebral levels or two vertebral bodies; (3) single-level or multilevel spondylosis with accompanying cervical stenosis; (4) multilevel spondylosis with kyphosis; (5) multilevel spondylosis with segmental instability; and (6) multilevel spondylosis with ossification of the posterior longitudinal ligament. The advantages of corpectomy and strut grafting are to provide more complete decompression, to decrease the risk of nonunion, and to restore a more normal cervical sagittal alignment.[10]

Indications for instrumentation are evolving in the setting of anterior corpectomy and strut grafting. As with ACDF, instrumentation may enhance fusion rates, particularly when three or more levels are involved. In certain instances, anterior plates may obviate the need for a posterior procedure or external immobilization in the early postoperative period. The addition of anterior plates, particularly at the inferior aspect of long strut grafts, may prevent graft extrusion.

The complication rate for anterior corpectomy and strut grafting increases as more corpectomy levels are incorporated into the procedure. The principal complications include pseudoarthrosis, graft displacement, and development of kyphosis. The choice between autograft and allograft balances the high complication rate associated with structural autograft harvest with the increased pseudoarthrosis rate reported with allograft.

Anterior cervical instrumentation specifics

In the past several years, there has been an explosion in terms of the number of available hardware systems and techniques for anterior instrumentation of the cervical spine. Concerns have been raised about complications associated with anterior instrumentation in the cervical spine, including hardware failure and implant dislocation leading to symptomatic dysphagia or esophageal perforation. The overall rate of hardware-associated complications with all types of anterior instrumentation has been estimated at approximately 5%, with some reports as high as 8%.[11] Plate length has been correlated positively with rates of hardware failure; pullout at the inferior end is the typical mode of failure.[12] Of particular concern are reports of increased rather than decreased pseudoarthrosis rates associated with anterior plating following ACDF. Some investigators have hypothesized that anterior plates may function to maintain distraction across disk spaces, preventing graft settling and thereby inhibiting fusion.[13] The debate continues as to which type of cervical plate is best suited for anterior cervical spinal fusion (Figures 2, 3, 4).

Surgical preparation

The patient is moved to the operating table and administered general anesthesia via an endotracheal tube. Cefazolin antibiotic (1 gram) is administered along with 1 gram of Solumedrol steroid. If severe spinal cord compression is present, 250 cc of 20% Mannitol and 40 mg of Lasix is administered intravenously to decrease the volume of cerebral spinal fluid in the dura.

The patient's arms are padded and tucked at the sides to prevent injury to the ulnar nerves. A small roll or 1000 cc IV solution bag is placed horizontally along the patient's back, bringing into view the anterior border of the sternocleidomastiod muscle. Both shoulders are pulled caudally utilizing 2-inch silk tape and attached to the foot of the table. This maneuver is extremely helpful when trying to radiologically localize the lower cervical spine region, as the shoulders inhibit the X-ray picture. If an autologous bone graft is to be harvested from the hip, a 10-pound sandbag is placed under the appropriate hip to bring the anterior iliac spine into view. The head is placed in a neutral position along the axial and saggital planes. Gardner Wells traction tongs are then placed on the patient, and he or she is placed into 15 to 17 pounds of traction (Figure 5).

Fluoroscopic scout films are taken to identify the appropriate level. Once this is accomplished, the skin is scratched with a needle at the affected level. A marking pen is not used because the mark would wash off during the surgical skin prep.

The skin prep consists of mechanically scrubbing the skin for six minutes with a 1:1 mixture

FIGURE 4

Surgical Dynamics Aline plating system.

FIGURE 5

Final patient position for anterior cervical fusion.

of iodine scrub and iodine solution. After blotting the site with a sterile towel, the circulator changes gloves and proceeds to paint the skin with the solution. If a hip graft will be harvested, the appropriate hip is also prepped in this manner. The draping technique varies from surgeon to surgeon.

Surgical procedure

Soft tissue dissection (Figures 6, 7)

Prior to making the incision, the scout X-ray films using fluoroscopy are checked again to confirm the correct levels. Using a #20 blade, a transverse anterolateral skin incision is made on the left side of the neck from the medial border of the sternocleidomastid muscle to the lateral edge of the trachea. Small surface bleeders are coagulated using a monopolar coagulator. The dissection is carried through the subcutaneous fat using the monopolar electrosurgical pencil. A small Gelpi retractor is then placed in the wound, and the dissection is further carried down until the platysma muscle is encountered. Using Metzenbaum scissors and Pott-Smith forceps with teeth, the platysma is divided parallel to the skin incision.

Subplatysmal dissection is carried 2 to 3 cm in all directions to gain exposure of multiple levels (Figure 8). Any large venous structures encountered in the dissection are ligated with 2-0 silk ties and divided using the bipolar cautery and Metzenbaum scissors. Pushers mounted on a Beckman (Tonsil) clamp are used to separate the space between the anterior border sternocleidomastiod muscle and the pretracheal fascia and strap muscles. Again, this dissection is carried along the whole area that is to be fused. If the field is obscured by the omohyoid muscle, it can be divided electrosurgically.

The longus colli muscles are the next structures to be encountered. They are separated from the anterior longitudinal ligament and retracted laterally. Once sufficient exposure is achieved, an 18 mm hand-held Cloward retractor is placed in the wound, retracting the esophagus and the trachea medially while the surgeon is utilizing the pushers and suction to retract the carotid sheath laterally.

The underside of the trachea and esophagus are bluntly dissected away from the anterior longitudinal ligament using

FIGURE 6 Back table set-up.

FIGURE 7 Mayo stands set-up.

pushers. Any small venous bleeding points are controlled using bipolar electrosurgery.

A needle is placed into the affected disk space and another X-ray image is used to confirm the correct levels. Once this is accomplished, a self-retaining retractor is placed into the wound. Many hospitals utilize the BlackBelt® retractor system. This system has a variety of widths and lengths of blades to choose from. This makes the surgeon able to maintain exposure of one level or several levels at once. The retractor is placed into the site in two directions, medially and laterally, and rostrally and caudally. This makes it simple for the surgeon to apply the plate without the aid of hand-held retraction. Extreme care must be taken not to distract the soft tissues too aggressively to avoid esophageal erosion.

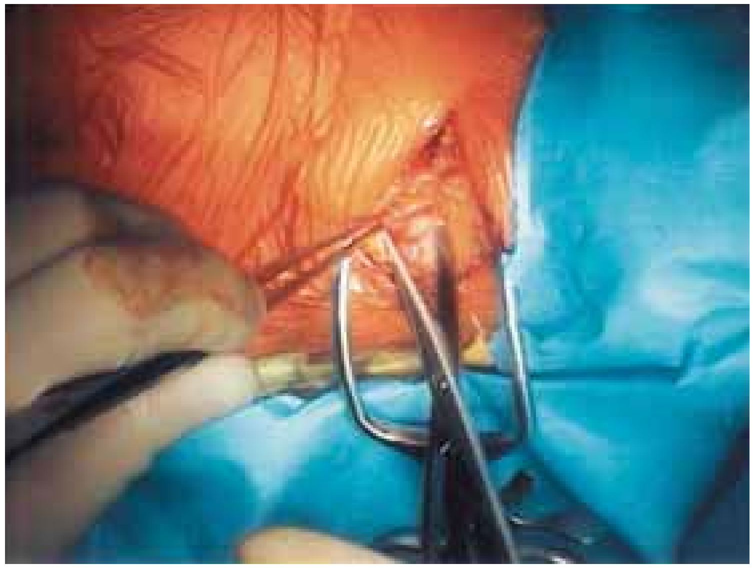

FIGURE 8

Operative photograph of initial dissection of the platysma muscle.

FIGURE 9

Operative photograph of a fibular strut implanted in a multi-level corpectomy site.

Decompression of the bony elements

The anterior longitudinal ligament is incised electrosurgically along the affected levels and dissected laterally away from the spine using a periosteal elevator. A vertebral distraction device that consists of 14 mm screws and a ratchet type distracter body is then placed into the vertebral bodies adjacent to the affected levels. This provides ample distraction of the posterior and anterior elements of the spine, thus decompressing the spinal cord and nerve roots.

A corpectomy is performed utilizing a high-speed drill with a fairly large (9 mm) cutting burr. Once the major bony decompression of the anterior two-thirds of the vertebral body and disk is complete, the surgeon begins the finer decompression of the spinal cord.

A microscope may be brought into place; however, sufficient illumination and magnification may be achieved using high-power loupes and a headlight. Using a #11 blade, the posterior longitudinal ligament is incised with attention paid not to damage the underlying dura. Bipolar electrosurgery may be used to stop any small bleeding points that may arise in the layers of the ligament.

A 2 mm Rhoton hook is then passed between the ligament and the dura to create a plane for the Kerrison rongeur to fit. A 2 or 3 mm 40° upbite Kerrison rongeur is used to remove the ligament overlying the central portion of the dura. A Kerrison rongeur with a thinner foot-plate is advised for this part of the operation. The tighter, more lateral portions of the dura and the foramen are decompressed with a 2 mm Kerrison. The foramen are inspected closely with a 3 mm blunt nerve hook to ensure that there is no impingement of the nerve root by bony spurs and/or disk fragments. These are removed with Kerrison and pituitary rongeurs respectively.

Once the surgeon is satisfied with the decompression of the spinal cord, a high-speed drill with a 3 mm matchstick-type cutting burr is used to decorticate the rostral and caudal end plates of the adjacent vertebral bodies. Hemostasis of epidural bleeding is achieved with Gelfoam® and topical Thrombin.® The disk space is measured for height and depth using a Caspar caliper or other measuring tool. The wound is soaked in saline containing antibiotics; the self-retaining retractor is relaxed, and attention is turned to preparation of the bone graft.

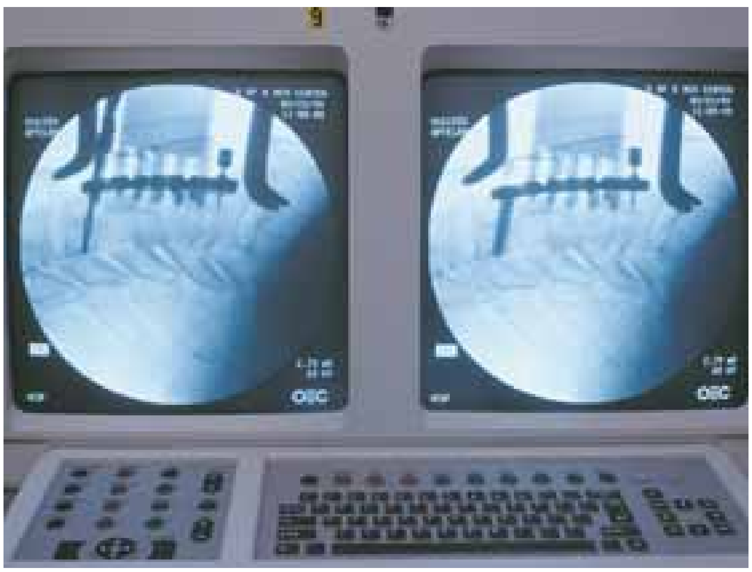

FIGURE 10

Photograph of fluoroscopic images showing the screw implantation procedure.

Bone graft preparation

There are two options of bone graft. Either harvest an autologus graft from the patient's hip or use allograft bone from a cadaver. With respect to pain, it has been reported that the hip graft site is much more painful than the neck site; therefore, the allograft is offered to the patient before the patient's own bone is offered. This has proved to be very reliable. Regardless of which bone graft is used, it must be fashioned to fit into the surgical site. Utilizing saws, drills, or rongeurs, the bone graft is tailored to fit in the fusion site. It must fit snugly enough to provide adequate load bearing to increase bony fusion, as well as be shallow enough not to compress the spinal cord behind the graft. If a fibular strut is used, bone taken from the corpectomy can be placed in the medullary canal of the fibular to provide a matrix for new bony growth to occur in the canal. The bone graft is then placed into the surgical site and tamped into place using a footed bone impactor and a small mallet, while gentle distraction is provided along the longitudinal axis of the neck (Figure 9). Once the surgeon is satisfied with the placement of the graft, the distraction pins are removed and the graft is probed to ensure firm seating and proper positioning. The holes created by the distraction pins are plugged with bone wax rolled into the shape of the hole.

Plate preparation

A cervical plate is chosen and compared to the X-ray to confirm that the superior and inferior screws of the plate will enter the adjacent vertebral body adequately (Figure 10). The plate should extend from near the top of the uppermost vertebral body incorporated in the fusion to near the bottom of the lowermost vertebral body, without impinging upon the subjacent disk spaces.

Most plates are pre-bent to an optimal angle of cervical lordosis, but they should be further optimized to sit flush on the vertebrae without gaps and to not rock when digital pressure is alternately applied to either end or side-to-side. A bending tool is utilized to increase or decrease the lordotic curvature of the plate by making a series of corrections along the plate. Small sequential corrections should be made to avoid overcorrecting, since repeated bending and unbending can weaken any metallic device and should be avoided.

It may be helpful to mark the midline above and below the plate placement site to assist in vertical alignment. This can be easily done at the time of initial spine exposure. A temporary fixation pin is then inserted in the plate to ensure that unnecessary movement of the plate does not occur during the placement of the screws.

Drilling

Normally, plate placement and drilling are done under fluoroscopic control to optimize selection of plate length and to optimize screw placement. Cranial and caudal screws are usually angled within the vertebrae, again increasing holding power. Their paths are carefully controlled to avoid entering the adjacent disk space.

By carefully aligning the fluoroscopic images of the facet joints of each vertebrae, the surgeon can be assured that a true lateral image is seen and precisely place bicortical screws by fully drilling the posterior cortex.

Tapping

In the case of bicortical screws, the holes should be tapped after they are drilled. By tapping fully to the posterior cortex, the assurance of firm screw engagement is gained. This must be done under fluoroscopic control, as tactile feedback when tapping is inadequate to determine the depth safely. Again, care must be taken to use true lateral images.

Screw Placement

The correct screw length is selected based on the depth information obtained during drilling or by utilizing a depth gauge. The screws are tightened firmly but not to excess (Figure 11). It is recommended that each screw be fully or nearly fully tightened on insertion prior to placing the next screw. This is repeated for as many screws as the surgeon wishes to place. Final tightening of the screws ensures that the heads are below the surface of the plate.

Many cervical plating systems on the market have a locking screw feature that helps prevent backing out of the screw. If this is the case, the locking screw is then engaged (Figure 12). After completing the bone screw placement at the ends of the plate and at any desired intermediate levels, as well as into any strut grafts, the temporary fixation pins are removed (Figure 13 a, b).

Closure

The wound is irrigated copiously with saline containing antibiotics, and fine hemostasis is achieved

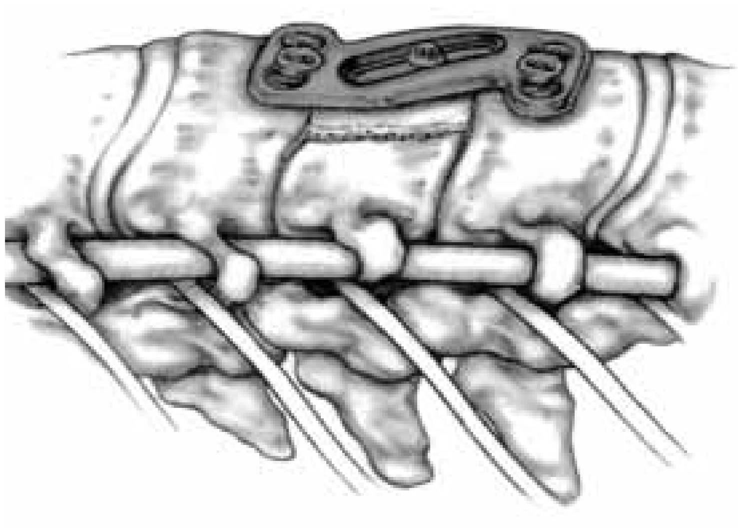

FIGURE 11

Artists representation of the final construct.

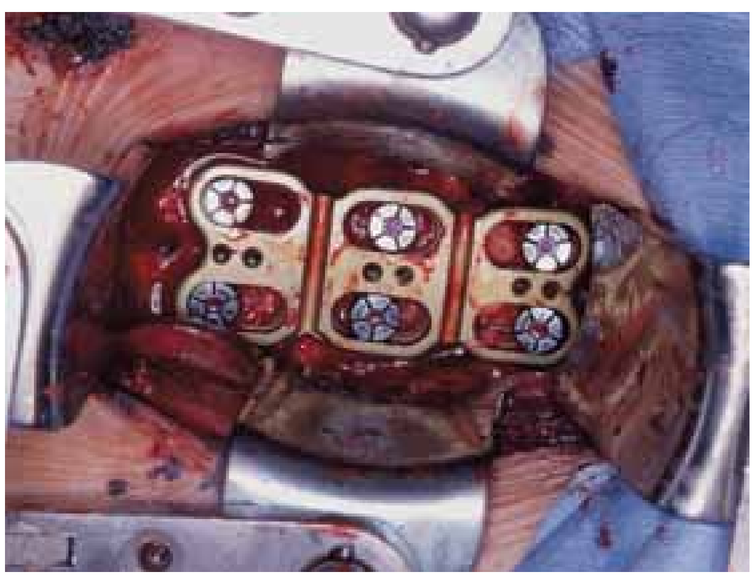

FIGURE 12

Operative photograph of a completed construct with locking mechanism engaged.

using the bipolar coagulation. After removal of the self-retaining retractor, inspection of the longus colli muscles and other soft tissues is performed. A small drain is placed in the wound, which is usually removed within 24 hours.

The platysma muscle is reapproximated using 0 Vicryl on a CT-2 (J 727D) needle in an interrupted fashion. The subcuticular layer is closed using interrupted 3-0 Vicryl suture on an X-1 (J 790D) needle. Any skin irregularities are corrected with 5-0 Plain Gut on a PS-4 (1632) needle. Mastisol, o Steri-Strips, a 1" x 3" Coverlet bandage, and a small Tegaderm bandage are placed on the wound. Betadine ointment on a 4" x 4" gauze sponge is placed around the drain site. The patient is moved back on the gurney and a cervical collar is applied. The anesthesia is reversed, and the patient is taken to the recovery room.

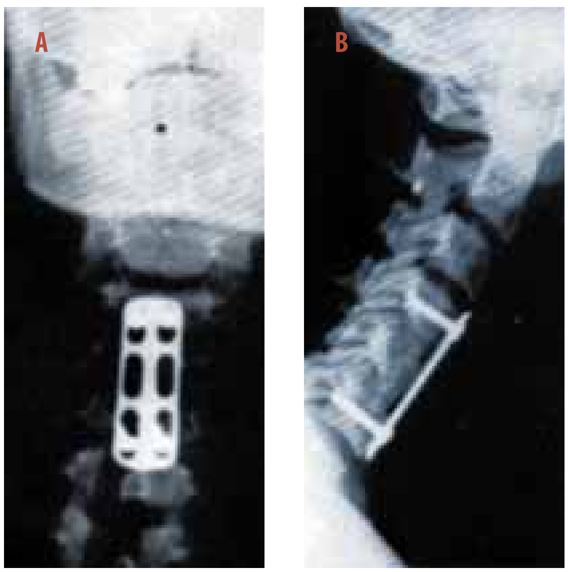

FIGURE 13

AP and lateral radiographs of a multi-level corpectomy, fusion, and stabilization.

Conclusion

Advances continue in the development and utilization of instrumentation for surgical treatment of cervical spine pathology and fusion. Strong evidence suggests that cervical spine instrumentation increases fusion rates, maintains cervical lordosis, and maintains or restores stability when appropriately employed. Such instrumentation may obviate the need for postoperative rigid external stabilization in many patients.

Clinical outcomes can be optimized and the potential for complications can be minimized, if the surgeon remains abreast of the continuously evolving indications, techniques, and instrumentation for treatment of the degenerative cervical spine.

About the author

Jeffrey J Cortese, CST, has been a certified surgical technologist for six years. A graduate of Baker College, Mt Clemens Campus, Cortese is employed at Mt Clemens General and St Joseph's Mercy of Macomb Hospital in Clinton Township, Michigan. He is also a student at Oakland University where he is obtaining his bachelor's degree in biology with specialization in anatomy.

Aknowledgments

I wish to thank my wife, Dawn, for her friendship and support in all of my endeavors. I also wish to thank John L Zinkel, MD, PhD, FACS, Medtronic Sofamor Danek, and Aesculap for their assistance in obtaining the images in this article.

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Images used courtesy of Medtronic Sofamor Danek and Aesculap.

MARKET OUTLOOK Spinal Fixation and Instrumentation

Charlie Whelan

The market for products used in spinal surgery and rehabilitation is one of the fastest growing sectors of the US orthopedics industry, both in terms of revenues and in terms of technological innovation. In 2001, the US market for spinal implants alone was estimated to have accounted for approximately $1.3 billion in revenues.

The spinal surgery patient base is expanding. Approximately 10 million Americans seek treatment for chronic back pain every year, and 10 percent of those people have surgery. Less invasive technologies, more spinal surgeons, and improved techniques and technologies that improve success rates and allow for greater numbers of patients to qualify for surgery have all lead to growth in the market.

Fixation instrumentation, the rods, screws, plates and other components used to fuse vertebral levels together, is the largest and most lucrative sector within the US spinal market.

The US market for spinal fixation instrumentation was estimated to have generated more than $951 million in 2001 and is forecasted to grow to more than $2 billion by 2008. Sales of constructs for use in the lumbar spine compose nearly half of all revenues for the market. The cervical market is growing rapidly, but the thoracic market is growing at a more modest rate.

Pedicle screws, rods and transverse connectors are the most important elements of most modern fixation constructs in the lumbar and thoracic spine, but laminar hooks, plates and wire are also used to varying degrees depending on surgeon preference and the needs of the patient. While pedicle screws are popular, facet screw systems are also being used by some surgeons who desire a less stiff, lower profile construct. Use of laminar hooks is reported to be on the decline as improved designs of pedicle screws replace them. As these more expensive pedicle screws are used, market revenues have risen sharply.

Charlie Whelan is a consultant for Frost & Sullivan, a San Jose, California-based growth consulting company. This information was excerpted from the report on US Spinal Surgery Markets, Frost & Sullivan, July 16, 2002.