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Orthotic Management of the Surgically Stabilized Spine in Quadriplegic and Paraplegic Patients

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Recent developments in the diagnosis and understanding of spinal dysfunction have affected both surgical and orthotic management of post-traumatic spine instability. The diagnosis of spinal instability has been clarified by clinical study of its natural history and by application of advanced imaging techniques.[1] Biomechanical studies have defined the role of each vertebral component in maintaining structural stability.[2] Surgical techniques and instrumentation for treating this problem have also evolved rapidly. These advances have resulted in an improved approach toward operative management of spinal instability. First, because the outcome of spinal injury can be more accurately predicted, surgery can be elected earlier for disorders that certainly would fail with nonoperative management. Surgery systems are available which maximize their effect in both obtaining and maintaining optimal spine positions. These reliable instruments have allowed surgeons to apply operative stabilization to a wider range of spine problems. Therefore, the orthotist is presented with an increasing number of patients who have undergone surgical stabilization and require postoperative immobilization. The purpose of this paper is to review the rationale for surgical treatment of traumatic spine disorders. This review will identify both the neurological and mechanical factors which must be addressed. Some of the instrumentation systems available and a few of their advantages and disadvantages and disadvantages will be examined. Finally, five separate areas of the spine will be identified and the special orthotic considerations in each region reviewed.

The primary concern in all injuries to the spine is the neurologic status of the patient. There are three general categories of neurologic injury for which reduction and stabilization of the spine improves recovery.[3,4] The first group includes the Brown-Sequard, anterior cord, and posterior cord syndromes. These are collectively known as incomplete cord syndromes. Stabilization of the spine in the presence of these lesions can significantly improve neurologic recovery in a majority of cases. The second class of neurologic injury which is benefited by stabilization is nerve root compression at the cervical level. The recovery of a single nerve root at the cervical level dramatically improves the function of the patient for the rest of his life. This recovery can be facilitated by stabilization. The final lesion helped by internal fixation is the progressive neurological deficit. Often motion at a site of neurologic damage aggravates the injury. Surgical stabilization can reduce irritation and promote recovery. Thus, irrespective of the integrity of the spine, surgery can be indicated for neurologic conditions alone.

However, loss of structural integrity can itself be an indication of operative treatment. If an area of bony disruption has resulted in significant deformity or has compromised the spine's ability to resist further deformity, surgical stabilization may be indicated. Authors have established guidelines for angulations and displacements to define this instability, but in all cases the final diagnosis of instability is largely clinical.[4] Pain at an area of compromised stability may also be an indication to reduce and stabilize a lesion. However, again the final determination is made on clinical grounds.

If internal fixation of the spine is indicated, the subsequent step is the selection of an instrumentation system and postoperative immobilization method for that patient. In dealing with quadriplegic and paraplegic patients, a major concern is skin insensitivity. Although postoperative cast immobilization provides the most rigid support and protection, it also presents the highest risk for skin and wound complications. It is generally agreed that orthoses which can be removed once or twice a day for skin inspection are best suited for neurologically impaired individuals.[5,6] The dilemma the surgeon faces is how to mobilize the patient as soon as possible after surgery, yet not use the rigid protection of casts. The solution to this problem has been the development of more rigid internal fixation systems for the spine.

Ultimately, the characteristics of the spinal column disruption determines the choice of instrumentation. Flexion, compression, and distraction are the three major mechanisms of spinal injury. Rarely does one force occur totally independent of the others. Usually one force is predominant with variable effect of the other two. The instability resulting from each of these forces, the instrument techniques used to counteract each of the deforming forces, and finally how the postoperative orthosis is also used to counter the mechanism of injury will be discussed.

Fractures which result primarily from flexion often involve crushing of the vertebral body anteriorly and distraction of the posterior elements. Generally speaking, instrumentation systems to correct this problem rely on three-point bending to reduce the fracture and maintain position. The Harrington system uses a single hook at either end of a rod to effect leverage against the kyphus and create an extension force. A long rod is required for this, so that excessive force is not generated under the single hook. In order to shorten the length of the rod and improve fixation, other systems have developed methods for attaching the rod to every segment over which it passes. The Luque, Wisconsin, and Cotrel-Dubosset instruments are examples of this segmental type fixation. These systems have three advantages over Harrington rods. By fixing the rod to each segment over which it passes, the large leverage force necessary to reduce the deformity is evenly distributed over several segments. This reduces pull-out failure. Because this force is distributed evenly, it is possible to reduce the total number of segments stabilized by the rod, thus preserving spinal motion segments. And finally, these segmental fixation systems are significantly more stable, which helps promote bony fusion of the injured segment. Another method of obtaining three-point reduction while improving instrument fixation is the use of transpedicular screws for placement of the hardware. This system uses a short plate placed over the vertex of the kyphus, and then screws placed through the plate are firmly anchored to the uninjured vertebra above-and-below the fracture. As the screws are tightened, the kyphus is slowly reduced. These devices involve the least number of normal vertebral segments to achieve reduction. They are exemplified by Steffee and Roy-Camille plates.

The segmentally fixed rods and transpedicularly anchored plates described above have excellent immediate stability. The major requirement of the postoperative orthosis is to reduce the stress on the implant by preventing repetitive forward bending of the patient. Orthotic requirements for Harrington rods systems are more demanding. With only single hook attachment, Harrington rods require an orthosis which generates a supplementary three-point bending force to reduce the possibility of hook pull-out. Because there are multiple unfixed segments where fusion is expected to occur, postoperative mobilization should be rigid enough to prevent non-unions from rotation and side-bending movements.

In fractures where axial compression is the major deformity, the vertebral body can burst both anteriorly and posteriorly. To reduce the fracture, an instrumentation system capable of distracting vertebral segments is chosen. Again, Harrington rods can be used in this situation. They have a hook in one end that can be ratcheted against the rod to distract and pull apart the segments above and below the crushed vertebra. Segmental wiring alone is ineffective in reducing vertebral body burst fractures. However, many surgeons first use Harrington rods to counteract the compressive force, then use wires attached to the rod at every level to get the advantages of segmental wiring. This combination is lightly referred to as "Harri Luque." Plates anchored to the spine with transpedicular screws are incapable of generating a distracting force. An experimental Swiss system attaches a threaded distractor to the spine with screws and can be used to distract burst-type fractures.

Orthoses cannot effectively counteract an axial load, or the results of the compressive mechanism of injury. Therefore, the orthosis is used exclusively to protect the implants from stress while the bone graft is consolidating. Again, the orthosis is most clearly indicated when Harrington rods are the only instruments maintaining the reduction. These single hook rods are subject to dislodgement if excessive bending or torsional forces are encountered.

The loss of structural integrity resulting from distraction injuries has different implications in the diagnosis and treatment of this instability. While flexion and compression forces generally cause anterior bony collapse, distraction injuries tend to cause posterior ligament disruption. Since the injury is a traumatic tearing of ligaments and discs, the instrumentation is used to compress or pull the separated segments together. In the thoracolumbar spine, hooks enclose the vertebrae above and below the site of injury and are connected by a threaded rod. Turning of the rod slowly approximates the hooks and reduces the deformity. However, this type of injury predominantly occurs in the cervical spine. In this location, wires are usually used to draw the separated segments together. Because of the ineffectiveness of ligamentous healing, bone graft fusion is used in conjunction with internal fixation.

Postoperative orthotic management in this situation is more complementary than supplementary. Whereas the internal fixation stabilizes in flexion, it offers little resistance to extension. Therefore, the orthosis should emphasize stability in extension.

For the sake of completeness, orthotic management after anterior spinal decompression and fusion should also be mentioned. When this procedure is performed, most of the affected vertebra is removed and replaced with a block of iliac bone graft. Present anterior spine instrumentation uses a threaded rod attached to the spine with screws to afford stability. Control of motion in all planes by the orthosis is required in this clinical situation.

The previous section dealt with the indications and techniques of spinal internal fixation, with emphasis on the role of postoperative orthotic management. Next, five regions in the spine and some specific orthotic requirements for each will be identified. Particular emphasis will be placed on whether a specific injury requires an orthosis to restrict or only to reduce intervertebral motion. When an orthosis restricts intervertebral motion, less than ten percent of normal motion is possible at that segment with the orthosis in place. An orthosis which restricts motion is used when either no or minimal internal fixation is used to provide stability. When up to 30% of motion at an intervertebral segment is possible while wearing an orthosis, the orthosis is said to only reduce intervertebral motion and not restrict it. A reduction orthosis is indicated to protect inherently stable fractures or spines internally stabilized secondary to surgery.

The first anatomic area to be discussed is the upper cervical spine. In this area, instability can result from fractures of the atlas, from fractures of the odontoid process, and from disease processes such as rheumatoid arthritis and tumors. Orthoses generally are inadequate in restricting intervertebral motion between the occipito-atlanto-axial segments. Therefore, for virtually any upper cervical disorder requiring restriction of intervertebral motion, application of a halo and vest is indicated.[7] One possible exception is the SOMI brace, which can be used to effectively restrict instability from ruptures and attrition of the transverse ligament of the atlas.[7]

The second anatomical area is the lower cervical spine. This extends from C3 through T1. Restriction of motion in this region is required in at least three situations. One is a flexion injury which compresses the vertebral body anteriorly and disrupts ligaments posteriorly. A second need for restriction is for extension injuries which avulse both the anterior longitudinal ligament and the intervertebral disc. A final situation is postoperative management of lower cervical fusions in which no internal fixation is used. In these situations, a cervicothoracic four-poster device should be used. If only reduction of intervertebral motion is required, then application of a Philadelphia collar is all that is necessary. The usual clinical situation needing reduction of intervertebral motion is immobilization after posterior cervical stabilization with wires.

The third anatomical region lies between T3 and T10. The thoracic region possesses the most inherent stability of the entire spine. For this reason, the bracing requirements are minimal. If no internal fixation is performed, the stabilization afforded by the thoracic cage need only be supplemented by a thoracolumbosacral orthosis (TLSO) to ensure maintenance of position. Segmental type operative fixation is especially suited for the thoracic spine. When this is performed, often no postoperative orthosis is required. Postoperative immobilization is still required in the thoracic spine when Harrington instrumentation is employed.

In the fourth region, the thoracolumbar junction, the use of orthotic management is dependent on whether or not surgical stabilization is performed and if so, which instruments are used. In this area, from T11 through L3, the typical fracture occurs from a combination of flexion and compression forces and is termed a "burst" fracture. Nonoperative management of this lesion relies on bracing to create an extension moment to reduce the amount of collapse during healing. Operative treatment has a combined goal: to reduce and hold the fractured segments while leaving mobile as many normal lumbar segments as possible. For this reason either segmentally attached rods or transpedicularly applied plates are used in this area. Since these systems possess significant inherent stability, the TLSO provides effective postoperative immobilization. This orthosis has been demonstrated to be effective for the upper lumbar spine.[8]

The final anatomical area, the lumbosacral spine including L 4, is least subject to traumatic fractures. It does, however, present some interesting challenges to obtaining effective immobilization. Operative treatment in this area should also preserve as many mobile lumbar segments as possible. With L 4 fractures, the lumbosacral articulation can often be maintained. However, the more rare L5 fractures usually require fusion to the sacrum. Because of the need for short but extremely rigid spinal instrumentation, systems using transpedicular fixation are favored for lumbosacral fusions. Although this fixation method is rigid, the high stresses at the lumbosacral junction dictate that external immobilization be used, especially if two level fusions are attempted. The TLSO has almost no ability to immobilize the lumbosacral motion segment. Therefore, the use of a one-half spica cast is recommended for use after lumbosacral surgery.[8]

In summary, the role of orthotics in the postoperative management of spinal instability is critical. Because the lack of normal sensation precludes the use of casts in quadriplegics and paraplegics, the proper fabrication and application of an orthosis is essential. Knowledge of the original fractures forces, as well as an understanding of the principles of operative stabilization, can assist the orthotist in managing the postoperative immobilization of the injured spine.

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