Posterior cervical spine fusion with tension-band wiring

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The goal of fusing the subaxial cervical spine is immobilization of the motion segment to prevent instability and neurological compromise.22 The need for fusion can occur in circumstances of trauma, tumor, infection, and progressive degenerative conditions that result in instability such as rheumatoid arthritis.

In cases of trauma, the most common injuries occur as a result of flexion and distraction loads, causing posterior ligamentous instability.3 Posterior ligamentous instability is not always appreciated when viewed on radiographic studies but is most important to consider when choosing an operative approach for stabilization.14,25 In their study using a canine model, Whitehill and colleagues29 have shown that in the face of posterior ligamentous instability anterior stabilization approaches do not result in a construct that can handle physiological flexion loads. Therefore, in instances in which anterior decompression of neurological structures is not necessary, posterior procedures are the technique of choice. In addition, the advantages of a fusion technique that allows earlier mobilization of trauma patients are well recognized.2,12

In cases of degenerative disease or tumor, consideration must be given to preventing neurological compromise caused by decompression of vital structures, as well as to ensuring the stability of the cervical spine by prevention of progressive or delayed instability. In many of these instances, posterior cervical fusion is a useful adjunct.

In 1957, Rogers20 described his successful technique for wire and bone-graft stabilization of the cervical spine. Since then various techniques and instrumentation have been added to the literature, including clamps, plates, and modifications of posterior wiring.1,4,8,11,17,18,26,30 We were impressed with a particular construct, first described by Segal, et al.,21 and later by Davey, et al.,10 known as tension-band wiring. This pin-and-wire construct provides excellent stability in flexion and, when intact facet joints are tightened by the construct, some stability in limiting both extension and rotation, which have been noted in other posterior fusion constructs.20,30 We have made certain modifications to this technique that simplify the procedure, and describe our results in 55 consecutive patients.

Clinical Material and Methods

Patient Population

We performed subaxial posterior cervical-spine fusion on fifty-three consecutive patients from September 1987 through December 1993 at Albany Medical Center. Two additional patients were recently (within 6 months at this writing) operated on by the first author (T.J.L.) at the University of Pittsburgh Medical Center. The operations were performed for trauma in 41 cases, degenerative disease in 13, and tumor in one case. The 30 males and 24 females ranged in age from 15 to 76 years (mean 34.4 years). The three groups of patients, those with trauma, degenerative disease, and tumor, are presented separately.

Patients With Trauma. The 41 patients who suffered trauma included 27 males and 14 females, ranging in age from 15 to 72 years (mean 30.9 years). The causes of their injuries included 21 motor vehicle accidents, 12 sports-related injuries, and eight falls. The neurological statuses of the patients on presentation were indicative of a complete spinal cord lesion in 10 patients, an incomplete one in 12, and radiculopathy in nine patients; 10 patients were neurologically intact. Indications for surgical correction included the presence of a grossly unstable fracture and/or a ligamentous disruption in 38 patients, including four in whom attempted halo immobilization failed, and three pa-
tients who experienced delayed instability after 3 months of halo fixation. All patients underwent posterior cervical fusion with tension-band wiring. One motion segment (two adjacent vertebrae) was fused in 17 patients, two motion segments (three vertebrae) in 15 patients, three motion segments (four vertebrae) in eight patients, and four motion segments (five vertebrae) were stabilized in one patient. Postoperatively, 30 patients were immobilized in a Philadelphia collar, seven in halo fixation, three by means of a four-poster brace, and one in a SOMI brace.

**Patients With Degenerative Disease.*** Thirteen patients were included in the category “degenerative disease.” Eleven of these patients suffered osteoarthritic changes that resulted in mechanical dysfunction and pain, one patient had rheumatoid arthritis with subaxial subluxation, and one patient had pain and neurological deterioration secondary to progressive kyphosis after trauma. For the most part, the patients with degenerative disease were neurologically intact, except for the posttraumatic patient, who presented with a worsening Brown–Séquard syndrome, and two patients with radiculopathy. The rationales for surgery included pain in the case of 11 patients and progressive instability, according to criteria outlined by White, et al., in the case of three patients. One patient had both mechanical neck pain and gross instability. All patients underwent subaxial posterior cervical fusion with tension-band wiring as well. Twelve of the 13 patients were immobilized postoperatively in a Philadelphia collar and one in halo fixation. Nine patients had one cervical motion segment fused; one patient had two; two patients, three; and one patient, four.

**Patient With Tumor.** The sole patient with a tumor presented as neurologically intact but with neck pain and a grossly unstable spine with tumor infiltration in the C-4 vertebral body. Because of an extremely poor prognosis, tumor excision was not attempted. Rather, the patient underwent a two-motion segment fusion (C3–5) with tenotomy and application of methyl methacrylate. Because of an extremely poor prognosis, tumor excision was not attempted. Rather, the patient underwent a two-motion segment fusion (C3–5) with tenotomy and application of methyl methacrylate instead of bone grafting, followed by radiation treatment. No postoperative immobilization was indicated.

**Description of Surgical Technique**

Early fracture reduction and traction is implemented in trauma patients. After awake intubation, which in trauma cases is performed fiberoptically, the patient is turned to the prone position. Traction is maintained and the patient is kept awake during positioning to monitor potential changes in neurological status. In nontrauma cases, three-point head fixation is used. The neck is prepared in sterile fashion from the base of skull to the upper thoracic spine. The sterile preparation is spread laterally and anteriorly for later pin placement and the iliac crest is prepared for bone-graft harvest as well. After injection of a local anesthetic, a linear incision is made and the spinous processes and laminae are exposed in standard supperiosteal fashion. Preoperative x-ray films are obtained for checking alignment and intraoperative x-ray films for position verification. Once all of the soft tissue is removed, a lateral stab wound is made so that a 3/32nd threaded Steinmann pin can be passed perpendicularly through the paraspinous musculature to the spinous process to be instrumented. The pin, which is located on a hand-held drill, is passed through the midsection of the spinous process just above the spinolaminar junction and trimmed in the wound, leaving 15 to 20 mm of pin on each side. The lamina and spinous processes are gently decorticated with a high-speed drill, and corticocancellous bone, obtained from the iliac crest, is added. Wire is then passed around the pins in a figure-eight fashion and tightened to approximately 10 lb/in² (Fig. 1). Early in our series, we used 16-gauge Luque wire, but switched to multistrand threaded cables when these became available for ease of placement and superior strength. Additional bone graft is added and a multiple layered closure is accomplished. It should be noted that a smaller Steinmann pin can be used if a small spinous process is encountered. Previous descriptions of this technique advocated passing the pin through both the bone graft and spinous process. We have simplified this by passing the pin through the spine only and laying corticocancellous bone graft directly on the lamina and spinous processes.

In patients with degenerative disease or a posterior fracture, care must be taken to avoid nerve root and/or spinal canal compromise when tightening the construct. This may necessitate performing foraminotomies over the nerve roots or removal of hypertrophied ligamentum flavum. Overextension can also be avoided by placement of a block bone graft between the spinous processes prior to wire tightening.

**Results**

There was no operative mortality in this series. There was one nonoperative death in the case of the one patient with tumor who died within 6 months of the operation from her primary disease. As of this writing, two patients are less than 6 months postoperative and one patient who demonstrated successful bone fusion has since been lost to follow up. The remaining 51 patients have been followed for an average of 3.9 years (range 9–83 months). Generally, patients will be discharged from follow-up care 1 year after successful surgery; however, numerous patients in this series have been followed for a longer period.

Successful bone fusion was obtained in 50 of 52 patients (96%) with two cases of pseudoarthrosis occurring, one in the trauma population and one in the degenerative group. Successful fusion was determined by postoperative radiographs, including flexion–extension films, demonstrating the absence of both movement and bone arthrosis at the fused segments. These radiographs were reviewed by the authors (operating surgeons) as well as by independent radiologists. No patient worsened neurologically. In the trauma group, the 10 patients with complete spinal cord lesions had their lesions remain complete and all 10 patients who were neurologically intact remained that way. The nine patients with radiculopathy had their problem resolve and seven of the 12 patients with incomplete spinal cord lesions showed some improvement. Of the 13 patients in the degenerative disease group, both patients with radiculopathy had resolution of their problem and the 10 neurologically intact patients remained intact. The one posttraumatic patient with longstanding Brown–Séquard syndrome showed slight improvement. Of the 11 patients with mechanical pain, 10 had complete resolution or greater than 50% improvement in their symptoms.

Special mention must be made regarding the patients...
with radiculopathy. Most of the traumatic cases of radiculopathy occurred with unilateral facet dislocation. If the patients were successfully reduced in preoperative traction and the preoperative CT scan demonstrated a patent foramen, the patients were fused \textit{in situ} without the need for foraminotomy and with resolution of their radiculopathy. If the radicular pain was due to a bone fragment in the foramen or if reduction was incomplete, foraminotomy and exploration of the nerve root were accomplished. In the degenerative disease group, all of the cases were fused without foraminotomies because it was believed that dynamic motion was responsible for nerve root irritation in the absence of a herniated disc or obvious foramin al stenosis. The average operative time for the procedure was 2 hours and blood loss rarely exceeded 400 cc.

Complications included one wire breakage and seven pulmonary problems, such as prolonged intubation and pneumonia, all of which occurred in the trauma patients. There was one cervical wound seroma and one bone graft site infection. One trauma patient required extension of fusion for a delayed progressive kyphotic deformity above the initially fused segments. Seven patients experienced a loss of reduction and required substitution of a halo after initial use of a Philadelphia collar. Other than one patient with rheumatoid arthritis, all of these were trauma victims and all had a level “skipped” secondary to posterior fracture and/or defect. None of these patients worsened neurologically and all went on to fuse uneventfully. The C5–6 level was involved most often, being fused in 38 cases; C4–5 in 20 cases; and C6–7 in 19 (Fig. 2).

**Discussion**

The goal of operative intervention in the cervical spine is to decompress neurological structures and to ensure the stability of the spine.\textsuperscript{12} The need for surgical intervention can occur in instances of trauma, infection, degenerative disease, and tumor. The cervical spine can be approached either anteriorly or posteriorly for the purposes of decompression and/or fusion. Benefits of early mobilization after trauma have long been recognized.\textsuperscript{2,12}

The question arises as to the treatment of trauma patients with halo fixation or surgery. Lemons and Wagner\textsuperscript{16} have addressed this issue by showing that severe vertebral body injury (loss of greater than 40% vertebral body height), severe ligamentous injury (translational deformity greater than 20% of body width, sagittal angulation greater than 15°, or a positive “stretch test”), or both, significantly correlate with failure of nonoperative stabilization. Therefore, posterior fusion is often warranted in trauma patients.

Since Rogers\textsuperscript{20} presented his results with posterior wiring in 1957, various methods for posterior fusion, as well as anterior procedures, have been advocated. In instances of trauma, the most common injuries are distractive flexion injuries, which cause posterior ligamentous damage that results in instability in flexion.\textsuperscript{3} Whitehill and colleagues\textsuperscript{29} also noted that burst fractures with resultant anterior instability and retropulsion of bone into the canal will also lead to posterior ligamentous instability. Although clearly there may be a need for anterior decompression of the spinal cord, the necessity of posterior stabilization by fusion remains.

Posterior fusion procedures have been shown to be superior to anterior approaches alone in terms of clinical outcome as well as in animal models. In a canine model exhibiting both anterior and posterior instability, Whitehill
and colleagues demonstrated that anterior fusion alone was insufficient to provide a stable construct. Other experimental studies have also provided data indicating that in the face of posterior ligamentous disruption, anterior procedures alone are inadequate for stabilization. Clinically this has been documented by Stauffer and Kelly and Capen and coworkers in trauma patients. Ranawat, et al., demonstrated a lack of long-term stability and neurological improvement after anterior fusion in patients with rheumatoid arthritis. Therefore, in almost all instances of instability in which there is concern about posterior ligamentous compromise, posterior fusion procedures are necessary.

Once the posterior approach has been selected, the tension-band construct described above offers some advantages over other fusion methods. By passing the pin through the spinous process, the technique avoids potential neurological risks associated with sublaminar wires and lateral mass screws. It is a simple procedure that takes little time, involves little blood loss, and results in a high fusion rate. It has been further simplified by the introduction of flexible multistrand cables. There has been no increased morbidity or infection rate as a result of passing the pins through the paraspinal muscles. Bone graft is necessary, however, and a good bone fusion is the ultimate goal. Although we used methyl methacrylate in one case of short life expectancy, we recognize the findings of experimental studies that indicate the long-term inadequacy of a methyl methacrylate construct.

With regard to strength, White has noted that the ideal stiffness for a cervical spine construct is not known. However, it should fall into a category somewhere between an extremely rigid plate and too much motion, both of which can result in failure of fusion. Little biomechanical work has been performed on the tension-band construct, but Wilber, et al., speculate it may be comparable in terms of strength to the triple-wire technique of Bohlman as described by Weiland and McAfee. Coe and associates discovered that there was no strength difference when comparing the relative stiffness of Roger’s wiring, triple wiring, and lateral mass plates using cadaveric spines. Gill and colleagues demonstrated that there was no statistically significant difference in either flexion or extension between various posterior fixation methods. Therefore, it is our contention that the tension-band wiring procedure described in this paper will provide excellent strength in terms of stiffness and adequate stabilization in flexion and, when facets are intact, in extension to allow postoperative mobilization with a Philadelphia collar. Indeed this has been our experience as the current data demonstrate. Therefore, the tension-band construct provides the strength and equivalent fusion rate of any available technique while being a safe, easy method to use.

The complications discussed might be expected in any extensive series on cervical spine fixation. The only exception would be in the cases of the seven patients who had loss of initial reduction. Because none of these patients worsened neurologically, they were placed in halo fixation without attempts at reduction and allowed to fuse in situ. There was no breakage of the construct or of the spinous processes. The halo fixation effectively arrested any future slippage and all went on to fuse uneventfully. One slip occurred in the case of the patient with rheumatoid arthritis, presumably due to degeneration of the discs and facet joints that occurred with a resultant horizontal facet-joint orientation. The other six instances involved trauma patients who had posterior fractures that obligated us to “skip a level” when wiring (for example, wiring of C-5 and C-7 and skipping C-6). None of our patients who did not have a level skipped had loss of reduction, whereas all our patients who did have a level skipped experienced some loss of reduction. Presumably these patients also had facet damage that allowed horizontal motion. In such instances in which there is extensive posterior element damage or facet disruption, and a level cannot be incorporated continuously into the construct, it is recom-
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...recommended that a facet joint or lateral mass plate fusion be used. If the tension-band construct is to be used, halo fixation is necessary. We have used, and advocate, lateral mass plating when this situation has arisen in light of our experience described above.

Segal, et al., 21 in 1981 and then Davey and associates 10 in 1985 described their preliminary results using tension-band wiring in small groups of patients. These authors noted excellent fusion rates and a stable construct. To our knowledge, the 55 patients included in our study represent the largest series of posterior cervical fusions using the tension-band wiring technique, although we have simplified the original procedure. In summary, this technique may be advantageous in that it is simple to perform, with little blood loss and a short operative time; it provides excellent stability in flexion and, when facets are intact, in extension and rotation as well. The technique involves fusion of a minimum number of motion segments and allows early mobilization, which requires only a hard collar for support and, nevertheless, results in an excellent fusion rate. It is, therefore, our contention that cervical tension-band wiring should be added to the neurosurgical armamentarium for posterior cervical fusions.

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References