Texas Scottish Rite Hospital rod instrumentation for thoracic and lumbar spine trauma

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The authors present their experience with 28 patients who had incurred unstable thoracic or lumbar spine fractures and who were intraoperatively stabilized with the Texas Scottish Rite Hospital (TSRH) universal instrumentation system. These patients were treated over a 1-year period and reflect an evolving insight into the treatment of thoracic and lumbar spine trauma with universal instrumentation. The TSRH instrumentation system appears equivalent to the more established Cotrel-Dubousset system in most respects. The construct design of the TSRH system facilitates the safe application of a rigid spinal implant. No cases of instability or pseudoarthrosis were observed during an average follow-up period of 9 months, (minimum 3 months). As the surgical treatment plan evolved, shorter and more compact constructs were increasingly utilized. There were no cases of instrumentation failure, regardless of the number of spinal levels fused or the number of levels instrumented. The value of using short rods when possible is emphasized: they may decrease the incidence of delayed instability and discomotrelation to loosening at the hook/bone interface compared to that observed when long-rod systems are used in association with short spine fusions causing a fusion/instrumentation mismatch.

KEY WORDS • spinal instrumentation • spinal fusion • spinal stabilization

The application of universal spinal instrumentation techniques to the treatment of thoracic and lumbar spine fractures has greatly enhanced the surgeon’s ability to gain immediate and sustained spinal stability. The largest body of experience with universal spinal instrumentation in spine trauma to date has been the Cotrel-Dubousset (CD) system. 9,10 We present our recent 1-year experience with the treatment of 28 thoracic and/or lumbar fractures at the University of New Mexico using a newer form of universal instrumentation, the Texas Scottish Rite Hospital (TSRH) spinal instrumentation system.+ This report offers some preliminary results and illustrates the utility and efficacy of this new technique.

Clinical Material and Methods

Case Material

The series comprises 28 patients who presented with unstable thoracic and/or lumbar spine trauma at the University of New Mexico over a 12-month period ending June 30, 1990, and who underwent decompressive spine surgery with the accompanying placement of a TSRH universal instrumentation system. All 28 patients were graded neurologically at admission and at 2 to 4 months following surgery according to the spinal cord injury grading scale of Benzel and Larson9 (Table 1). The clinical data and specific characteristics of each operation are presented in Table 2.

All but three patients underwent surgery within 2 weeks of injury. One (Case 13) was operated on for a progressive spinal deformity 2 years posttrauma. Another (Case 17) underwent surgery 3 weeks following injury; this delay was due to a prolonged stay at an outlying institution. The third patient (Case 27) had a 1-month delay due to the presence of severe abrasions over his entire back that required prolonged wound care to heal.

Diagnostic Studies

In all patients, x-ray films, computerized tomography scans, and magnetic resonance (MR) images were obtained of the unstable spinal segments. All those undergoing a lateral extracavitary decompression and fusion procedure1 underwent preoperative spinal angiography in order to demonstrate the presence or absence of a radiculomedullary artery in the region of the operative approach. If such an artery was demonstrated, the spine was approached from the other side.
Instrumentation for spine trauma

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Neurological grading system of thoracic and lumbar spine injuries with regard to myelopathic function*</th>
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<tbody>
<tr>
<td>Grade</td>
<td>Definition</td>
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<tr>
<td>I</td>
<td>complete functional neural transaction: no motor or sensory function below the level of injury</td>
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<td>II</td>
<td>motor complete: no voluntary motor function below the level of injury with preservation of some sensation</td>
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<td>III</td>
<td>motor incomplete—nonfunctional: minimal nonfunctional voluntary motor function below the level of injury</td>
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<td>IV</td>
<td>motor incomplete—functional (nonambulatory): some functional motor control present below the level of injury that is significantly useful (for example with transfers) but not sufficient for independent walking</td>
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<td>V</td>
<td>motor incomplete—functional (limited ambulation): motor function allows walking with assistance or unassisted, but significant problems secondary to lack of endurance or fear of falling limit patient mobility</td>
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<td>VI</td>
<td>motor incomplete—functional (unlimited ambulation): ambulatory without assistance and without significant limitations other than one or more of the following: 1) difficulties with micturition; 2) loss of nerve root function that significantly impede ease of ambulation; 3) slightly uncoordinated gait</td>
</tr>
<tr>
<td>VII</td>
<td>normal: neurologically intact with the exception of minimal deficits that cause no functional difficulties</td>
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</table>

*Grading according to the classification of Benzil and Larson.1 Because of the occasional limitation related to spinal instability, "ambulatory" is defined as the motor and sensory function consistent with the ability to walk. Table reproduced with permission.

Decompression and Fusion Procedures

All 28 patients underwent a decompression and fusion procedure with the placement of TSRH rods. The procedure involved either lateral extracavitary decompression and fusion3 or posterosilateral (transpedicular) dural sac decompression with posterior fusion (posterior decompression and fusion) (Table 2). All patients receiving a lateral extracavitary decompression and fusion procedure underwent anterior interbody fusion following the placement of instrumentation.13 This approach involves the extrapleural or extraperitoneal exposure of the lateral aspect of the spine, which allows for anterior spinal decompression under direct vision, anterior interbody fusion, and placement of dorsal spinal instrumentation (all through the same incision). Patients receiving a posterior decompression and fusion procedure had posterior or posterosilateral fusion following the intraoperative placement of the instrumentation system. Spinal canal translational deformities were reduced when appropriate.

Patients underwent lateral extracavitary decompression and fusion unless the spinal MR images demonstrated unquestionable evidence of complete spinal cord disruption in the presence of a complete (Grade I) myelopathy. Posterior decompression and fusion was performed in the latter patients because of the less invasive nature and more direct approach to stabilization of the spine involved in this procedure.

<table>
<thead>
<tr>
<th>TABLE 2</th>
<th>TSRH rod placement for thoracic and lumbar spine trauma*</th>
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<tbody>
<tr>
<td>Case No.</td>
<td>Age (yrs).</td>
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*TSRH = Texas Scottish Rite Hospital.
†Preoperative grade/postoperative grade: The neurological grading system9 is set out in Table 1.
‡Type of spinal operation performed, excluding instrumentation: LEDF = lateral extracavitary spinal decompression and fusion; PDF = posterolateral decompression and fusion.
§Mode of application of instrumentation to the spine: Dist = distraction; comp = compression; neut = neutral. (S) denotes the "short-rod two-claw" technique (see text for explanation).

Hook Placement

All four patients with high thoracic fractures and accompanying complete (Grade I) myelopathies underwent placement of sublaminar hooks (Fig. 1). In the 16 patients in whom hook placement was below L-1, sublaminar hooks were uniformly utilized, regardless of the patients' neurological status (Fig. 2). Because placement of hooks (positioned above the fractured segment) on the transverse processes and/or pedicles offers less structural security than placement of sublaminar hooks, longer-rod systems were used in the 10 patients with this hook design in an attempt to neutralize the tenuous nature of the hook/bone interface (Fig. 2).

In the second 6 months of the study, we began placing sublaminar hooks in the region of the spinal cord (above the conus medullaris) without the use of long rods in patients with incomplete myelopathies in order to accomplish an increase in stability similar to that achieved with long rods. A "short-rod two-claw"
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myelopathies (Grade I), and 15 had incomplete myelopathies with some sparing of neurological function below the level of the injury (Grades III to VI). All but one patient with an incomplete myelopathy improved at least one neurological grade postoperatively; no neurologically normal patient deteriorated. No patient with complete motor and sensory myelopathy improved, regardless of the type of operation performed. Table 2 summarizes this experience.

Complications
There were no instances of instrumentation failure, dislodgement, instability, or pseudoarthrosis during an average follow-up period of 9 months (minimum 3 months). One patient (Case 3), who had incurred an incomplete myelopathy (Grade VI) secondary to an L-2 fracture, had the sudden onset of a high-grade T-10 myelopathy (Grade II) 4 days following surgery. She had previously undergone an emergency thoracotomy for a ruptured thoracic aortic aneurysm at the time of admission and developed refractory hypertension. Following spine surgery, her blood pressure was very labile.

*S.R.T.C.* technique was used in these circumstances (five patients); this technique involves both upward- and downward-facing hooks on the same lamina ("claw") and is applied to the laminae above and below the fractured level. The S.R.T.C. technique was also used in one patient with a complete myelopathy and in one patient with an incomplete myelopathy secondary to an L-3 fracture.

The S.R.T.C. application of universal instrumentation systems is straightforward (Fig. 3). Small laminotomies are performed first, allowing for placement of the hooks; the rods are then contoured as indicated and attached to the hooks. Next, the hook/rod system is placed in a distraction, neutral, or compression mode.

**Rod Placement**

Placement of the rods was determined as follows: the compression mode was used when needed to maintain reduction of the spinal segments (seven patients, Table 2) (Fig. 4). Distraction was used when spinal compression could have resulted in neural impingement or spinal deformity and/or when it appeared intraopera-
tively that distraction would maximally augment sta-
bility (20 patients, Table 2). The rods were placed in a neutral mode when both spinal distraction and compres-
sion were contraindicated. This was judged to be the case if gross ligamentous disruption was present (allowing excessive distraction) or if spinal compression would exaggerate the spinal deformity or might increase neural compression (one patient).

In order to allow for the acquisition of a rigid quad-
lateral frame construct, TSRH Crosslinks were placed in all patients (Figs. 1, 2, and 4). An attempt was made to contour the rods to fit the patient's spinal anatomy in each case. Postoperatively, all patients were immobilized with either a cervicothoracic or a thoro-
columbar brace.

**Results**

**Neurological Function**

The location of the fractures in this series of patients ranged from T-3 to L-3. The patients ranged in age from 15 to 57 years. Preoperatively, two patients were neurologically normal (Grade VII), 11 had complete myelopathies (Grade I), and 15 had incomplete myelopathies with some sparing of neurological function below the level of the injury (Grades III to VI). All but one patient with an incomplete myelopathy improved at least one neurological grade postoperatively; no neurologically normal patient deteriorated. No patient with complete motor and sensory myelopathy improved, regardless of the type of operation performed. Table 2 summarizes this experience.

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Fig. 1. Postoperative x-ray film, anteroposterior view, in Case 5. The application of multiple hooks over a relatively short spinal segment that is difficult to stabilize allows for stability without the need for longer rods. Longer rods could not have been placed in this patient because of the proximity of the fracture level to the cervical spine.

Fig. 2. Postoperative x-ray film, lateral view, in Case 12. Utilization of transverse-process and pedicle hooks offers adequate but perhaps less than optimum fixation. Application of longer rods, as in this case, is required because of increased leverage obtained with a longer lever arm. The lower hooks were placed as a sublaminar claw. Below the conus medullaris, sublaminar hook placement is performed with less risk due to the absence of hook contact with the spinal cord.

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**E. C. Benzel, L. Kesterson, and E. P. Marchand**

384

*J. Neurosurg.* / Volume 75 / September, 1991

† TSRH Crosslinks manufactured by Danec, Memphis, Tennessee.
Instrumentation for spine trauma

and, just prior to neurological deterioration, her systolic blood pressure fell to 60 mm Hg. She was immediately noted to have incurred a complete motor myelopathy (Grade II). She had recovered to an ambulatory state (Grade V) at her 10-month follow-up visit and neurological improvement was continuing at that time. Her neurological deterioration was considered to be ischemic in nature. No other patient experienced perioperative neurological deterioration.

Three superficial wound separations occurred. These were believed to be related to repeated periods of prolonged pressure on the incision. Four patients complained at their 6-month follow-up visit of tenderness at one or both ends of the rods; all four had hooks placed beyond the extent of their fusion (a fusion/instrumentation mismatch). Two of these patients (Cases 3 and 9) have since undergone the uneventful removal of their entire instrumentation system (at 13 and 8 months following surgery, respectively). Both had significant tenderness near the upper end of the rods, and both had stable fusions at the time of instrumentation removal. These two patients enjoyed complete resolution of their pain syndromes following surgery.

Discussion

Early clinical experiences with the application of the CD spinal instrumentation system to spine trauma have already been published.4,6,9,10 Clinical data regarding the TSRH system in general or its specific application to spine trauma have not previously been available. The data presented here, therefore, represent the first documentation of the utility and efficacy of the TSRH system for the treatment of thoracic and lumbar spine trauma. It is also the largest clinical series published to date regarding the application of universal instrumentation to thoracic and lumbar spine trauma.

Hook Placement

Many factors must be considered prior to and during the application of any spinal instrumentation system. Important considerations pertaining to universal instrumentation techniques as applied to spine trauma include determination of the number and location of the hooks and the mode of application of the rods (that is, placement in a compression, distraction, or neutral mode). Universal instrumentation techniques are unique in this regard because they allow placement of multiple hooks in compression, distraction, or in a neutral mode.

The ability to place multiple hooks offers several advantages. Hook dislodgement and instrumentation failure are minimized by the application of multiple hooks (CE Johnston, et al., unpublished data) which widely distribute the "load of instrumentation." The use of multiple hooks can be expected to provide stronger instrumentation constructs than are obtained with less substantial systems (such as the Harrington distraction rod). The use of universal instrumentation techniques, however, is also associated with problems. They are more difficult to apply than less substantial systems and the risks of neural impingement and injury are greater. The difficulty of application, however, is somewhat neutralized as experience is gained by the surgeon (as in the present series).

Placement of multiple hooks with complex forces applied to the spine at multiple levels may offer a hidden element of error. For example, the intermediate hooks in a long-rod system may be inadvertently displaced due to rod distortion created by distracting or compressing the terminal hooks. This distortion may result in a ventral movement of the rod and its accompanying intermediate hooks. If the intermediate hooks were placed in a sublaminar position, their ventral movement could result in neural compression; pedicular placement could even result in nerve root or dural sac compression. These factors must be considered and

J. Neurosurg. / Volume 75 / September, 1991 385
continuously assessed during application. For this reason, intermediate sublaminar hook placement associated with long-rod systems should only be used in patients with complete myelopathy or in those requiring hook placement below the conus medullaris (Fig. 2).

Placement of transverse process hooks in the low thoracic and lumbar region is hampered by the absence of robust transverse processes. Consequently, sublaminar hook placement may be an acceptable alternative in this region.

The Short-Rod Two-Claw Technique

In order to avoid the difficulties associated with placement of intermediate hooks and the long-term sequelae related to the use of long rods, the SRTC technique (the utilization of upward- and downward-facing hooks on the same lamina (“claws”) applied to the laminae immediately above and below the fractured level) was applied to selected patients in this series. The “claw” in the SRTC technique provides augmented stability, thus partially negating the need for longer rods.

The advantages of the SRTC technique are significant. First, the procedure is technically easier to perform than instrumentation techniques spanning more segments and utilizing more hooks in complex arrangements. Second, less overall spinal “stiffness” and, thus, less patient discomfort is encountered. Third, and most important, once solid fusion is acquired, the rods and hooks do not move with respect to the spine. Consequently, delayed hook dislodgement and/or tenderness should not occur if bone fusion takes place. The need for rod removal is thus markedly diminished. The frequency of chronic back pain may also be reduced.

The SRTC technique is especially useful when the surgeon is faced with the need to apply a short rod segment, such as in the high thoracic or mid to low lumbar region. It is emphasized that the SRTC technique permits instrumentation of only the unstable level(s) and the intervening motion segments (Fig. 3). The fused levels, therefore, are the only levels instrumented. It is also emphasized that the SRTC technique is only applicable to situations with interbody fusions or where anterior axial stability already exists.

Based on our data, patients who have rods placed over more spinal segments than the number of levels fused may have an increased incidence of instrumentation loosening or discomfort, which may necessitate rod removal to relieve the symptoms. This is the reason, at least in part, for the not uncommon requirement for Harrington distraction rod removal following acquisition of spine fusion. Additionally, long-rod techniques may lead to degenerative changes in the facet joints, which may further contribute to the morbidity of this technique. These factors make the SRTC technique even more appealing.

The acquisition of a bone fusion is of paramount importance. Without this, instrumentation failure will eventually occur. Persistent intersegmental motion, which exists when a solid bone fusion is not acquired, will eventually result in failure at the metal/bone interface.

Crosslinking

An even distribution of forces between all of the hooks and their interfaces with bone is emphasized. Crosslinking the right and left rods together substantially increases the structural stability of any universal spinal instrumentation system. It increases the chance of maintaining an even distribution of forces applied to the spine by each of the hooks while the patient is moving, thus minimizing the risk that a single hook will fail. In a system where the loads at the hook/bone interfaces are not evenly distributed (that is, where there is no instrumentation crosslinking), failure at one of the hook/bone interfaces results in the application of increased stresses at the next weakest interface and its failure is then imminent. Each hook/bone interface, therefore, may fail in sequence, ultimately resulting in failure of the entire system. If, on the other hand, forces at the hook/bone interfaces are evenly distributed, failure at one point of metal/bone contact would require simultaneous failure at multiple points of contact. This would, in turn, require a substantially greater applied force or load to cause failure. The ability of a crosslinked system to resist failure is, therefore, substantially greater than that found in systems not crosslinked.

The TSRH Crosslinks system used in this series (Fig. 5) offers rigid crosslinking of the right and left rods. On the other hand, the CD crosslinking system (Device Transverse Traction, DTT) (Fig. 5) is not nearly as rigid (CE Johnston, et al., unpublished data). The TSRH Crosslinks system allows for the acquisition of a true quadrilateral frame construct. The DTT system does not offer this degree of stability, although it may be useful when the desired result is simply the maintenance of an appropriate inter-rod width, and not the acquisition of a rigid quadrilateral frame construct. It is of note that the TSRH Crosslinks system may be used with CD rods and hooks. The TSRH Crosslinks system does, however, have a higher profile than the DTT system and could theoretically result in increased overlying soft-tissue pressure necrosis.

Deformity Correction

If excessive deformity correction is necessary, modification of techniques used for scoliosis deformity correction may be helpful. For example, a 180° rotation of a rod that has been contoured to fit a flexion deformity allows the spine to be placed in extension. Similarly, a 90° rotation of a rod that has been contoured to fit a scoliosis deformity allows the spine to be placed in either extension or flexion, depending upon the direction of rotation. In any of these circumstances, in situ rod bending may be used to obtain the ultimately desired contours.

The importance of contouring the rod to “fit” the anatomy of the patient’s spine is emphasized. Subcutaneous rod protrusion or the attainment of a less than
Instrumentation for spine trauma

The CD System Versus the TSRH System

The CD and TSRH spinal instrumentation systems both allow instrumentation placement in a distraction, compression, or neutral mode. The TSRH system offers advantages and disadvantages similar to those of the CD system. The differences between the systems allow inherent system-specific advantages and disadvantages (Fig. 5). The CD system utilizes hex screws to attach the hooks to the rods, whereas the TSRH system uses eyebolts and nuts. The TSRH system may be more difficult to apply in cases of large or medially placed facet joints; however, this system encourages the use of open hooks (which facilitate ease of application without sacrificing the strength of the system at the hook/rod interface).

The TSRH system is more easily removed if necessary because removal of the system simply requires the removal of a nut. The CD system, on the other hand, requires rod cutting or bending since the hooks are more permanently attached to the rod by the hex screws (which are twisted off at the time of placement).

The CD rods are more malleable than the TSRH rods, thus, facilitating ex vivo and in situ rod bending. We have not observed problems associated with this malleability and they have not, thus far, been reported in the literature. Therefore, it seems that the degree of malleability associated with the CD rod offers some advantages without significant liability. The CD rods are also knurled (Fig. 5). The rough surface of the CD rod is important with regard to the method by which the CD hooks are secured to the rod. The hooks are attached by a hex screw, which requires a rough surface to minimize the chance of hex screw-and-hook slippage. Finally, the CD hooks are 11 mm thick at their interface with the rod, whereas the TSRH hooks are 14 mm thick. The thinner CD hooks facilitate the application of a claw, in that the hooks themselves may be approximated more closely. This allows for a tighter "grip" on the lamina.

Conclusions

The TSRH universal spinal instrumentation system is an acceptable alternative to the CD instrumentation system for the stabilization of the posttraumatic thoracic and lumbar spine. The experience presented here indicates that the TSRH system and similar techniques will play an expanding role in the treatment of such injuries in the future. With this system, the utilization of multiple hooks with shorter rods than have traditionally been employed is emphasized. This allows for a secure fixation, while simultaneously offering the advantage of immobilizing fewer motion segments.

References


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