Unilateral cervical facet dislocation: a biomechanical study of several constructs including unilateral lateral mass fixation supplemented by an interspinous cable

Laboratory investigation

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Object. Both ventral and dorsal operative approaches have been used to treat unilateral cervical facet injuries. The gold standard ventral approach is anterior cervical discectomy and fusion. There is, however, no clear gold standard dorsal operation. In this study, the authors tested the stability of multiple posterior constructs, including unilateral lateral mass fixation supplemented by an interspinous cable.

Methods. Six fresh human cervical spine specimens (C3–T1) were tested by applying pure moments to the C-3 vertebral body in increments of 0.5 Nm from 0 Nm to 2.0 Nm. Each specimen was tested in the following 8 conditions (in the order shown): 1) intact; 2) after destabilization via injury to the C5–6 facet; 3) with bilateral C5–6 lateral mass screws and rods; 4) after further destabilization by creating a right unilateral lateral mass fracture of C-5 (which rendered secure screw placement into the right C-5 lateral mass impossible); 5) with unilateral left C5–6 lateral mass screws and rod; 6) with unilateral C5–6 lateral mass screws and rod supplemented with an interspinous cable; 7) with a bilateral multilevel dorsal construct C4–6; and 8) after a C5–6 anterior cervical discectomy and fusion (ACDF) procedure with a polyetheretherketone graft and plate.

Results. The bilateral C5–6 lateral mass construct reduced the range of C5–6 motion to 33.6% of normal. The unilateral C5–6 lateral mass construct resulted in an increased range of motion to 110.1% of normal. The unilateral lateral mass construct supplemented by an interspinous cable reduced the C5–6 range of motion to 89.4% of normal. The bilateral C4–6 lateral mass construct reduced the C5–6 range of motion to 44.2% of normal. The C5–6 ACDF construct reduced the C5–6 range of motion to 62.6% of normal.

Conclusions. The unilateral lateral mass construct supplemented by an interspinous cable does reduce range of motion compared with an intact specimen, but is significantly inferior to a C4–6 bilateral lateral mass construct. When using a dorsal approach, the unilateral construct with a cable should only be considered in selected instances.

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Key Words • unilateral facet injury • anterior cervical fusion • posterior cervical fusion • stability

Both ventral and dorsal approaches have been used to reduce and stabilize unilateral cervical facet dislocations.7–10,13–15,17,20–22 Kwon et al.15 prospectively randomized patients with unilateral facet injuries to ACDF versus dorsal stabilization. Since both groups had similar fusion rates and patient-reported outcome measures, the authors concluded that their study “provided level 1 evidence that both the ventral and dorsal fixation approaches appear to be valid treatment options.”

Abbreviation used in this paper: ACDF = anterior cervical discectomy and fusion.

All 20 patients in the ventral group in the study of Kwon et al.15 underwent a 1-level ACDF procedure with plate placement. This is widely accepted as a “gold standard” ventral operation for stabilization of unilateral facet injuries. On the other hand, the 22 patients in the dorsal group received a wide variety of fixation constructs, possibly reflecting the lack of a “gold standard” dorsal construct. Of note, the number of dorsal levels fused in each patient is not clearly delineated. With the ventral technique, 2 vertebrae were fused in each case. Two or 3 vertebrae might be fused when a dorsal lateral mass technique is employed. Often, 3 levels are fused dorsally when an injury
to the inferior articular process of the rostral spinal level extends into the lateral mass, thus rendering it incompetent with respect to the acceptance of a lateral mass screw. In this situation, the incorporation of 3 vertebrae in the fusion construct, by incorporating an additional rostral uninjured segment, is prudent. The downside of such a strategy is that the mobility of the additional motion segment is lost. The question remains: is it truly necessary to extend the construct to include 3 levels?

In a human cadaveric study, Duggal et al. demonstrated that 1-level bilateral lateral mass plating is biomechanically superior to a 1-level ACDF. This “bonus superiority” raises the possibility that unilateral lateral mass fixation may sufficiently stabilize a fracture when injury to the inferior articular process of the rostral spinal level extends into the lateral mass. If not, a supplemental interspinous cable might provide enough additional stability to obviate the need to extend the construct to the uninjured rostral motion segment. To determine whether this is so, a biomechanical study was performed.

Methods

The goal of this study was to assess lateral mass fixation of the 2 lateral masses on the uninjured side, supplemented by an interspinous cable, as a novel alternative to a 3-level dorsal construct. Six fresh human cervical spine specimens (C3–T1) were thawed and stripped of soft tissue, leaving the ligaments and discs intact. The specimens were potted at T-1 in a mixture of Bondo (3M) and resin with the C7–T1 disc space in the horizontal plane. Two orthogonal rods were inserted into the C-3 vertebral body to apply pure moments. Five L-shaped markers, each consisting of 3 light-emitting diodes, were fixed to the vertebral bodies of C-3, C-4, C-5, C-6, and C-7 with 1 marker attached to the fixed base, which served as reference to the others.

Pure moments were applied to the C-3 vertebral body in increments of 0.5 Nm from 0 Nm to 2.0 Nm, utilizing loading arms, nylon ropes, and pulleys in intact and injured specimens.

Hybrid testing was performed (for the third, fourth, and fifth specimens) utilizing pure moments applied to the C-3 vertebral body until the overall motion in the instrumented specimens reached the overall motion in the intact condition. The specimens were tested in all 6 modes of motion: extension, flexion, left lateral bending, right lateral bending, left axial rotation, and right axial rotation. The positions of the light-emitting diodes were recorded using an Optotrak Motion Measurement System (Northern Digital) and were converted into 3 rotations (flexion/extension, lateral bending, and axial rotation) using rigid-body kinematic principles in relation to the fixed base.

Each specimen was tested with the following sequence: 1) Intact: The specimens were tested in the intact condition without any injury. The intact data were used as a baseline with which the remaining cases were compared. 2) Initial destabilization: The specimens were destabilized by performing a unilateral cervical facet injury at the C5–6 level on the right side. First, the right C5–6 joint capsule was opened with a scalpel. A scalpel was also used to injure the lateral one-third of the disc adjacent to the facet. The specimen was then manually rotated until the inferior articular process of C-5 “jumped” over the superior articular process of C-6. The jumped facet was then manually reduced. 3) Bilateral C5–6 lateral mass screws and rods: The specimens were stabilized by inserting bilateral lateral mass screws and rods at C5–6. The Mageri technique was used to place all lateral mass screws in this study, and 3.5 × 14-mm lateral mass screws were used in all specimens. 4) Further destabilization: At this time, the right C5 lateral mass screw was removed. The specimens were further destabilized by creating a right unilateral lateral mass fracture of C-5 with a Kerrison instrument. This fracture started from the inferomedial aspect of the C-5 lateral mass and extended through the typical lateral mass screw entry site for either a Roy-Camille or Mageri technique, thus rendering secure screw placement into the right C-5 lateral mass impossible (Fig. 1). 5) Unilateral lateral mass screws and rod: The specimens, stabilized by the rod connecting the 2 left C-5 and C-6 lateral mass screws, were then tested. 6) Unilateral lateral mass screw and rod with interspinous cable: The rod connecting the left C-5 and C-6 lateral mass screws was left in place. A braided interspinous cable was placed from C-5 to C-6 after a fibular strut graft was placed between the C-5 and C-6 spinous processes. The cable was tightened to 20 foot-pounds. 7) Bilateral multilevel dorsal construct: A rod connecting C-4, C-5, and C-6 lateral mass screws was placed on the left side with another rod connecting C-4 and C-6 lateral mass screws on the right side. A C-5 lateral mass screw was not placed on the right given the injury to the C-5 lateral mass. 8) Anterior cervical discectomy and fusion: The lateral mass screws and rods were removed. A C5–6 discectomy was performed and a polyetheretherketone graft was placed into the interspace. A ventral plate was then fixed to the C-5 and C-6 vertebral bodies using 4.0 × 14-mm screws.

![Fig. 1. Illustration of the position of the right unilateral lateral mass fracture of C-5. The fracture was created with a Kerrison instrument. It started from the inferomedial aspect of the C-5 lateral mass and extended through the typical lateral mass screw entry site (as depicted by the 2 black lines), thus rendering secure screw placement into the right C-5 lateral mass impossible. The solid black circle indicates a typical lateral mass entry site.](image-url)
Biomechanical study of constructs for cervical facet injury

Statistical analysis, including a post hoc power analysis, was performed. Values for motion were obtained in the aforementioned 6 loading directions and averaged for each specimen and construct. Each value was normalized by dividing it by the initial motion in the intact spine; this was done to aid in statistical analysis and to account for differences in each individual spine. Student t-tests were performed.

Results

Averaged over all studied orientations, the bilateral C5–6 lateral mass construct reduced the range of C5–6 motion to 33.6% of normal. The unilateral C5–6 lateral mass construct was associated with an increased C5–6 range of motion (110.1% of normal). The unilateral lateral mass construct supplemented by an interspinous cable reduced the C5–6 range of motion to 44.2% of normal. The C5–6 ACDF construct reduced the C5–6 range of motion to 62.6% of normal (Fig. 2).

Averaged over all loading orientations, the 4 constructs performed statistically significantly better than the specimens that were subjected to a unilateral C5–6 facet injury and fracture of the C-5 lateral mass: C5–6 bilateral lateral mass construct (p = 0.0010), unilateral lateral mass fixation supplemented by an interspinous cable (p = 0.0401), bilateral C4–6 lateral mass construct (p = 0.0019), and C5–6 ACDF construct (p = 0.0142). The C5–6 unilateral lateral mass construct did not demonstrate a statistically significant advantage over the injured specimen (p = 0.1338).

Averaged over all ranges of motion, there was no statistically significant difference between C5–6 ACDF and unilateral lateral mass fixation supplemented by an interspinous cable (p = 0.2904).

Discussion

Injury Creation and Instrumentation

We wished to create identical injuries in all 6 cadaveric specimens. In our review of the literature, cervical facet injuries created by hydraulic machines frequently resulted in multiple different injury patterns. For example, in one study, a hydraulic torsion testing machine was used to apply increasing amounts of torque to the subaxial spine until a unilateral facet dislocation occurred. This resulted in inconsistent injury patterns among the 6 specimens in that study. The articular process that dislocated was C-4 in 2 specimens, C-5 in 1 specimen, and C-6 in 3 specimens. In addition, bony injury to this articular process occurred in 5 of their 6 specimens with 4 different fracture morphologies. We felt that manually creating the injury was the best way to achieve a consistent injury in all 6 cadaveric specimens.

To create the initial facet dislocation, we first cut the facet capsule. One of the earliest cadaveric studies of cervical injuries showed that the joint capsule should be opened to create a facet dislocation. Injury to the soft tissues of the facet joint is also described in more recent experimental models of cervical facet injuries. We then used a scalpel to create an injury to the lateral one-third of the disc adjacent to the dislocated facet joint. This was performed because disruption of the disc adjacent to the dislocated facet is described in all specimens in 3 other experimental studies. Manually rotating the specimen until the inferior articular process of C-5 “jumped” over the superior articular process of C-6 was then performed. We chose not to damage the interspinous ligament since such damage was not experimentally created in 2 studies and did not occur consistently in a third model of unilateral cervical facet injury. The jumped facet was then manually reduced; this has been described previously.

When we proceeded with further destabilization, we again wished to create a standard injury that could be replicated in all specimens. To do this, we used a Kerrison instrument to simulate a fracture that started at the inferomedial aspect of the C-5 lateral mass and extended through the typical lateral mass screw entry site for either a Roy-Camille or Magerl technique (Fig. 1), thus rendering secure screw placement into the right C-5 lateral mass impossible. While some have reported using an osteotome or a high-speed drill to experimentally create bony facet injuries, we felt the Kerrison instrument offered the best and most controlled technique for creating the desired fracture. Creating the injury with an osteotome requires a forceful blow with a mallet, which risks dislodgement of the cadaveric specimen from either the rostral or caudal potted end. In addition, the Kerrison instrument does not “jump” or “chatter,” which can occur with the high-speed drill and as a result lead to variability in fracture patterns.

For our posterior instrumentation, the Magerl technique for placing lateral mass screws was chosen as prior studies showed this trajectory is slightly safer than the Roy-Camille technique with no significant difference in pullout strength at C-5 and C-6. We used 3.5 × 14 mm lateral mass screws in all specimens in this study. The decision to use this screw length was supported by a paper that analyzed 1026 lateral mass screws that were consecutively placed in 143 patients. The vast majority of screws placed in that study were 14 mm in length and...
there were no reported injuries to the vertebral artery or nerve roots. Many spine surgeons do not consider bicortical lateral mass screws a routine technique and for this reason we did not strive to obtain bicortical screw purchase. We felt it was important to only use commonly performed techniques so that the conclusions of this study would be relevant to the majority of practicing spine surgeons. For this same reason, we also decided not to use cervical pedicle screw fixation. Although some groups have published extensively on this technique,\textsuperscript{1,24} pedicle screw fixation in the C3–6 levels is not routinely performed by most spine surgeons. The small size of the cervical pedicle typically results in a relatively high rate of suboptimal screw placement. For example, in their study of a series of 620 cervical pedicle screws placed, Yukawa et al.\textsuperscript{24} reported, “57 (9.2%) demonstrated screw exposure (< 50% of the screw outside the pedicle) and 24 (3.9%) demonstrated pedicle perforation (> 50% of the screw outside the pedicle).” Because of these concerns, Xu et al.\textsuperscript{23} concluded in their review that “pedicle screw fixation at the C2 and C7 pedicles in conjunction with use of plates for occipitocervical or cervicothoracic plating is becoming an accepted technique; however, pedicle screw fixation should not be routinely used at the C3–6 levels.”

For the posterior cabling, a braided interspinous process cable was placed and tightened to 20 foot-pounds in all 6 specimens. Shapiro et al.\textsuperscript{19} reported tightening an interspinous process cable to 20–30 foot-pounds in 22 patients undergoing surgery for cervical facet injuries. In our clinical practice, we have found that 20 foot-pounds is typically sufficient while 30 foot-pounds may lead to hyperextension of the injured level with widening of the ventral disc space. Another way of preventing undesired hyperextension with cabling is to place an interspinous bone graft prior to tensioning the cable. Benzel and Kessler\textsuperscript{6} described a technique of placing structural bone graft between spinous processes in conjunction with interspinous wiring in 50 patients with cervical spine injuries. In that study, the authors achieved this by using a split-thickness tricortical iliac-crest graft. We were unable to obtain a cadaveric ilium, and therefore used fibular allograft as the interspinous bone graft in the present study.

For the anterior instrumentation, 14-mm–long screws were used. This is a typical screw length used during anterior discectomy and plating procedures. Although bicortical screw purchase is biomechanically superior to unicortical screw placement, bicortical purchase is not typically performed because of the risk of spinal cord injury. Again, we felt it was important to only use commonly performed techniques so that the conclusions of this study would be more relevant to clinical practice.

Analysis of the Different Constructs

This human cadaveric study demonstrated that unilateral lateral mass fixation, supplemented by an interspinous cable, is more stable than an injured specimen averaged over all ranges of motion (p = 0.0401). It was also more stable than unilateral fixation alone. Unilateral fixation alone is not useful, as it was less stable than an intact specimen, likely related to an exaggerated “hinge effect.”

There was no statistically significant difference between ACDF and unilateral lateral mass fixation supplemented by an interspinous cable (p = 0.2904), thus this construct deserves further consideration. It should be compared with other dorsal instrumentation techniques, such as the bilateral C4–6 construct. While the bilateral C4–6 lateral mass construct did not incorporate a screw into the fractured C-5 lateral mass, its stability was still far superior to unilateral lateral mass fixation supplemented by an interspinous cable (44.2% of normal versus 89.4% of normal). This suggests that unilateral lateral mass fixation supplemented by an interspinous cable should not routinely be used. While the C4–6 construct does take away an additional motion segment, this is probably a small sacrifice in most instances given its superior stability.

As already mentioned, the unilateral lateral mass construct supplemented by an interspinous cable still demonstrated statistically superior stability to the injured specimen and may be useful in selected instances. It may be potentially useful if extending a construct an additional rostral level is technically demanding or dangerous. For example, it could perhaps be employed if the unilateral facet injury occurred at the C3–4 level in a patient with bilateral hypoplastic C-2 pars. In this situation, the risk of injury to the vertebral artery with a pars screw at C-2 is high, and a unilateral lateral mass construct at C3–4 supplemented with a cable would avoid that risk. Another situation in which this construct could potentially be useful is in a patient in whom concurrent ligamentous strain at more rostral levels is observed. For example, if a patient sustained a C6–7 unilateral facet injury with concurrent ligamentous strain at C4–5, it may be unsafe to use a C5–7 construct (Fig. 3). This would put more stress on the C4–5 level, compelling the surgeon to then consider incorporating C-4, thereby eliminating even more subaxial motion. This could also be avoided by limiting the construct to unilateral lateral mass fixation supplemented by an interspinous cable.

Power Analysis

In general, we prefer to perform a priori power analysis whenever possible. However, the degree of increased motion caused by the C5–6 facet injury was not known prior to experimentation, thus making a priori power analysis difficult. We therefore performed a power analysis retrospectively. Post hoc power analysis was performed to determine the power of our study in detecting a difference, if one exists, between the C5–6 ACDF and the unilateral lateral mass fixation supplemented with an interspinous cable.

To determine if unilateral lateral mass screw fixation with interspinous cabling is or is not superior to C5–6 ACDF, 36 cadaveric specimens would need to be tested to establish that there is a reduction of motion from 89% to 62% of normal with a power of 0.80 given an SD of 40%. The power of our study with 6 specimens for detecting this difference is 0.21.

Study Limitations

As described above, our power analysis demonstrat-
ed that 36 specimens would need to be analyzed to optimally power this experiment. Significant funding would be required to support this type of study.

Conclusions

Unilateral lateral mass fixation supplemented by an interspinous cable may be a useful construct for selected patients with unilateral cervical facet injuries. Further biomechanical studies with more cadaveric specimens could be performed to further analyze the constructs evaluated in this study. Clinical studies evaluating patients undergoing different types of stabilization procedures for unilateral cervical facet injuries should also be considered in the future.

Disclosure

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