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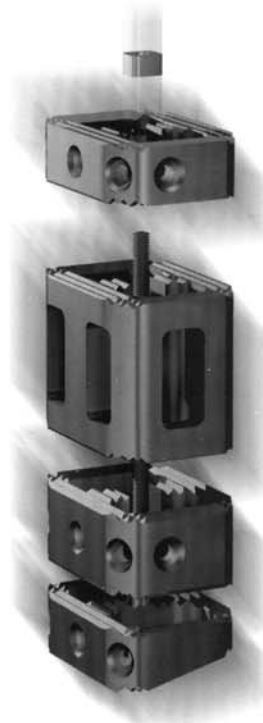
Use of Stackable Carbon Fiber Cages to Reconstruct the Anterior Column of the Spine Following a Complex L1-L2 Fracture-Subluxation



History

A 31 year-old woman was the victim of a 30-foot fall which resulted in multiple long bone, pelvis, and spine fractures. The woman landed on concrete and sustained burst fractures of both the L1 and L2 vertebral bodies. Additionally, she had a right hip fracture and a complex pelvis fracture which involved the right sacroiliac joint as well as comminuted fractures of the distal left sacrum. Her past medical history was remarkable only for a deep vein thrombosis in her left lower extremity which, due to a history of smoking and oral contraceptive use, had been treated with placement of a Greenfield filter.

Physical Examination

On arrival to the trauma center, she had significant weakness of both lower extremities. The severe pain of these fractures complicated her physical examination. She was able to wiggle her toes; however, she had only trace movements of both proximal lower extremities. She was areflexic in both legs and she had an L1 sensory deficit. A Foley catheter had been placed during the initial resuscitation but she did have sacral sparing to pinprick sensation in the perianal region.

Radiographic Imaging Studies

In addition to pelvis and long bone fractures, her plain film spine x-rays revealed significant fractures of both the L1 and L2 vertebrae (Figure 1). A computerized tomography (CT) scan demonstrated significant disruption of both vertebrae (Figure 2). At the L1 level, there was a 17% loss of height of the vertebra with 55% canal compromise. At the L2 level, a 50% height loss and a 70% canal compromise was observed. Coronal reconstructions revealed the appreciable loss of structural integrity of both injured vertebrae.

Management

Due to significant blood loss from a retroperitoneal hematoma, the patient was resuscitated in the Intensive Care Unit (ICU). Multiple blood transfusions were necessary to hemodynamically stabilize her. Aggressive management by the multidisciplinary critical care service successfully stabilized her condition over a 72-hour period. On the fourth day following her injury, she was taken to the operating room for a spinal decompression, fusion, and stabilization procedure. As marked disruption of both the L1 and L2 vertebrae was apparent anteriorly, as well as significant disruption of the posterior supporting ligamentous structures, the decision was made to perform an anteroposterior (AP or 360°) spinal reconstruction.

Figure 1A: – Lateral plain film radiograph – Fractures of both L1 and L2 vertebrae are evident; L1 has lost 17% height and L2 has a 50% reduction in height. There is no significant kyphotic angulation. The Greenfield filter is seen in the inferior vena cava.

Figure 1B: – Anteroposterior (AP) plain film radiograph – Fractures of L1 and L2 seen with significant rotational component with some translation leading to coronal plane imbalance/deformity.

Operative Treatment

The patient was positioned in the right lateral decubitus position with the left side up. An inflatable beanbag and tape were used to secure positioning and the table was flexed at the L1-L2 level. A left thoracoabdominal approach with resection of the left 11th rib was performed. Following release of the medial crura of the diaphragm, the region from T12 to L3 was able to be widely exposed. Comminuted fractures of both the L1 and L2 vertebrae were readily identified. Segmental vessels were ligated at the mid-vertebral body level of T12 through L3.

The Kaneda SR™ device was utilized. Staples were placed in the T12 and L3 vertebrae and 2 screws were placed into each vertebra. Placement was confirmed with fluoroscopy. Discectomies were performed at 3 levels (T12-L1, L1-L2, L2-L3) and corpectomies of L1 and L2 were performed. The bone from the disrupted vertebrae was preserved for later use in the fusion portion of the operation. Pedicle-to-pedicle decompressions were accomplished at each level which spared the anterior and far lateral cortices of bone. The dura was exposed from T12 superiorly to L3 inferiorly. There was no dural tears and, due to the degree of comminution of the fragments of bone, the corpectomies were able to be quickly completed.

After carefully removing all articular cartilage from the vertebral endplates of T12 and L3, the bony endplates were left intact. Large distracters, placed in the posterior vertebral body screws at T12 and L3, were used to restore anatomic height to the injured segments and fluoroscopy confirmed that over-distraction did not occur. A caliper was used to measure the span of the resultant defect. Stackable carbon fiber cages were then utilized to provide anterior column support. A 68mm defect had been measured which led to selection of a 66mm cage. After the cage was constructed, the center of the cage was firmly packed with a generous amount of autologous cancellous bone which had been preserved from the fractured vertebrae during the decompression portion of the operation.

Figure 2A: – Computerized tomography (CT) scan – axial view – Disruption of the L1 vertebra with retropulsion of bone fragment between the pedicles; the right pedicle is fractured; 50% canal compromise.

Figure 2B: - CT scan – axial view – Oblique fracture through L1 with angulation.

The vertebral bony endplates of T12 and L3 were then perforated in the mid-body region with a high-speed drill. The perforations were positioned in a location which would correspond to the central portion of the stackable cages where the cancellous bone had been packed. The bony endplates were preserved in the perimeter where the carbon fiber stackable cage would be in contact with the vertebrae. The cage was then positioned between the intact vertebrae above and below. Care was taken to ensure that the cage allowed for 2-3mm of clearance from the decompressed dura mater. Furthermore, care was taken to center the cage in both the sagittal and coronal planes. After the cage was positioned, the distracter was released which allowed for compression of the cage. At this point, the operating table was returned to a neutral position by "un-flexing" the table. This allowed for additional compression of the cage between the T12 and L3 vertebrae. Throughout the period while the table was being moved, the cage was directly visualized to assure that no change in its position relative to the dura occurred. After confirming that a 2-3mm space was present between the stackable carbon fiber cage and the dura mater, fluoroscopy was performed in both AP and lateral projections to confirm adequate positioning of the cage. Radiopaque beads in the periphery of the cage allow for accurate orientation with the intraoperative fluoroscopic images.

The rods for the KANEDA device were then secured to the screws at T12 and L3. These rods were then cross-linked to improve rotational stability. Following hemostasis, the thoracoabdominal wound was then closed in the routine fashion. The patient was then logrolled into the prone position on a second operating table for the dorsal stabilization procedure.

The posterior surgery consisted of stabilization with the Isola system from T11 through L4. Hooks were placed at T12 and L3, in a claw configuration, to re-establish a tension band posteriorly. Pedicle screws were placed at the T11 and L4 levels. The rods were connected and cross-linked. Generous amounts of autologous iliac crest bone were then packed over the transverse processes of T11-L4 bilaterally. A layered closure completed the operation. The total intraoperative blood loss was estimated at 600cc and operative time was 7 hours.

Figure 2C: - CT scan – axial view – L2 vertebra demonstrates 70% canal compromise with fracture of the left pedicle.

Figure 2D: – CT scan – coronal reconstruction – Marked disruption of the integrity of both L1 and L2 vertebrae is apparent.

Postoperative Course

The patient did very well postoperatively. She did not require any additional blood transfusions. Three days after the spinal reconstructive surgery, she underwent major reconstructive surgery for her pelvis and long bone fractures. These were uneventful. Postoperative plain film x-rays and CT scans, with sagittal and coronal reconstructions, demonstrated excellent decompression of the neural elements and alignment in both the sagittal and coronal planes (Figure 3).

She was transferred to a specialized spinal cord injury rehabilitation center for a four-week course of intensive therapy. During this time, she regained significant motor power in her legs and she was able to ambulate with a four-point walker. A post-void residual (PVR) urine volume determination revealed the PVR to be less than 50cc (within normal). She was maintained in a TLSO brace for 3 months postoperatively. After confirmation of alignment, when compared to her immediate postoperative radiographs and CT scans, the brace was discontinued.

At her one-year follow-up evaluation, she had full, normal power throughout both lower extremities. She had normal bowel and bladder function. Formal urodynamic testing was within normal limits. She did not require any assistive devices. Plain film radiographs, at one-year follow-up, demonstrate excellent alignment and a solid radiographic fusion (Figure 4). She has returned to her previous activities as a homemaker.

Figure 3A: – CT scan – axial view – Postoperative view at the L2 level demonstrates a pedicle-to-pedicle decompression; the carbon fiber cage is centered in the resultant defect and it is filled with autologous bone; a thin rim of bone is present anteriorly and on the right hand side.

Figure 3B: – CT scan – sagittal reconstruction – Postoperative image shows preservation of normal sagittal alignment with complete decompression of the spinal canal; the stackable carbon fiber cage fills the great majority of the bony endplates above and below.

Figure 3C: – CT scan – coronal reconstruction – Postoperative image of stackable carbon fiber cage, filled with autologous bone, restoring anatomic alignment in the coronal plane.

Figure 3D: – CT scan – axial view – Pedicle screws at the T11 level are securing the superior end of the instrumentation construct.

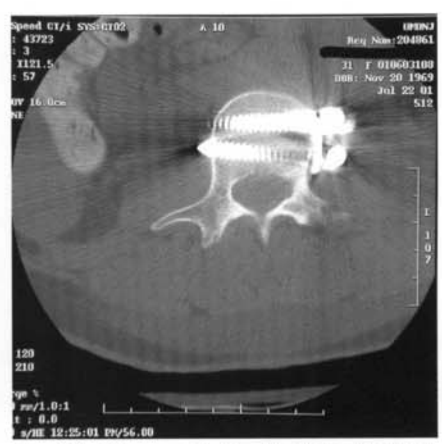


Figure 3E: – CT scan – axial view – Bicortical vertebral body screws, part of the Kaneda screw/rod stabilization construct placed anteriorly, are positioned to achieve triangulation to improve stability.

Discussion

In the case of severe thoraco-lumbar instability, the use of the Stackable Cage System by DePuyAcroMed™ offers several advantages over alternative methods. The flexibility of this system affords the spine surgeon the opportunity to select the optimal length to fit the bony defect. When using either structural autograft or allograft bone, this length of defect might be more problematic to fill. Iliac crest tends to curve and fibula does not have the requisite strength to span a defect this large at the thoracolumbar junction.

Titanium cages have been used to span long defects after corpectomies. There are numerous advantages of using stackable carbon fiber cages compared to these titanium cages for complex spinal reconstructions. Firstly, the modulus of elasticity of the carbon is quite comparable to the bone it abuts above and below. This characteristic makes the stackable carbon fiber cage less likely to "settle" or "piston" into the adjacent bone. This problem has been observed with titanium cages as far out as two years after initially successful spine surgery. Secondly, the stackable carbon fiber cage has a better "footprint" than titanium cages. This means that the area of contact is slightly more broad on the carbon fiber cage which allows forces to be dispersed more evenly. The stackable carbon fiber cage can also be sized in such a manner as to have the footprint of the cage approximate the vertebrae above and below very well. By fitting the stackable cage as far out on the periphery of the bony endplates, where biomechanical testing has shown the strongest bone to be located, the carbon fiber cage is less likely to perforate into the adjacent vertebral body. Finally, the stackable carbon fiber cage is radiolucent which allows for determination of fusion status to be greatly improved. A persistent problem with titanium cages is the difficulty in clarifying if a solid fusion has occurred. By placing radio-opaque beads in the periphery of the stackable carbon fiber cage, its orientation is able to be accurately determined while not interfering with the ability to assess fusion status.

With the ease of insertion of these stackable cages, the operating time can be shortened and generous amounts of cancellous bone are able to be situated in a compressive construct which is favorable for eventual fusion. For the assortment of reasons outlined above, stackable carbon fiber cages offer an excellent option for reconstructing the anterior and middle columns of the thoracolumbar spine following major anterior reconstructive procedures.

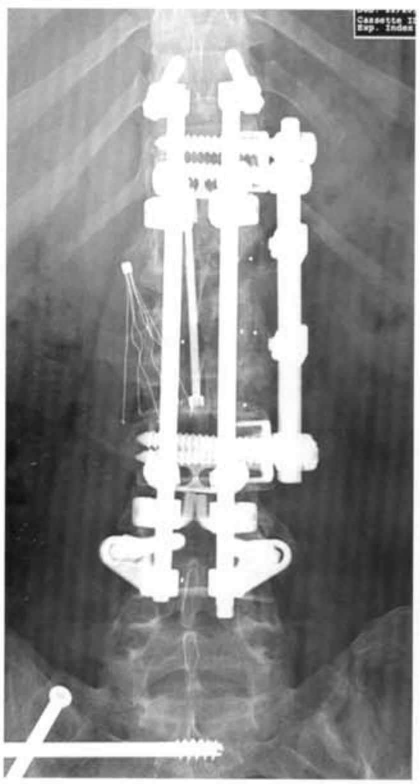


Figure 4A: – Plain film radiograph – AP view – At one year follow-up, plain films demonstrate excellent alignment has been maintained and a solid fusion has occurred.

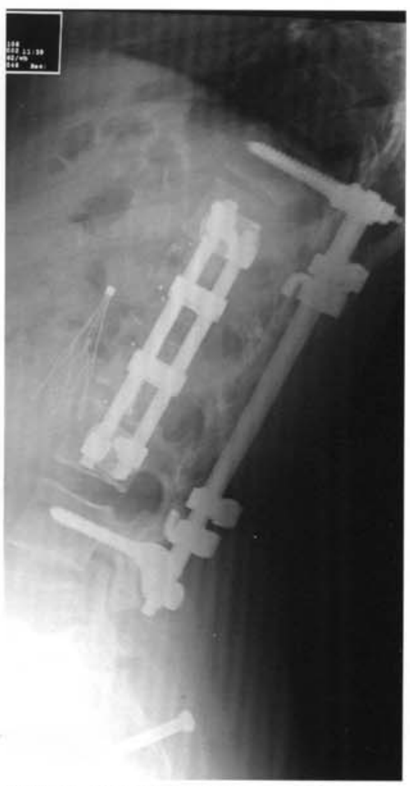


Figure 4B: – Plain film radiographs – lateral view – At one year follow-up, preservation of alignment and solid fusion is demonstrated. Hardware used to stabilize the pelvic fractures is visible inferiorly.