Scoliosis and Chest Wall Derotation Utilising Pedicle Screws and the Vertebral Column Manipulator Device

a report by

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The revolutionary design and capabilities of the Cotrel-Dubousset (CD®) Spinal Instrumentation System transformed the treatment of spinal deformities when it was introduced in the early 1980s. Prior to that, for nearly 20 years hooks were the primary implant used for fixation to the thoracic vertebrae. However, in the 1990s surgeons began to use lumbar and thoracolumbar pedicle screws at the lower end of spinal deformity constructs. Superior results of lumbar pedicle screws used for scoliosis correction have been confirmed at multiple centres, and the technique continues to be used today.

Since the introduction of CD instrumentation, the most difficult deformity to correct has been axial plane rotational malalignment. The novel 90º rod rotation manoeuvre espoused by Drs Yves Cotrel and Jean Dubousset was excellent for coronal and sagittal realignment of scoliosis deformities, but was found to be essentially a translational corrective manoeuvre in the axial plane, with minimal true derotation of the apical vertebrae and ribcage occurring.1

However, since the beginning of the new millennium, an increasing number of scoliosis surgeons around the world have been utilising pedicle screws in the thoracic spine. This technique has also been shown in many centres by many surgeons to be a viable option for thoracic fixation.2 Surgeons who have switched from hook to screw implants in the thoracic spine were initially impressed by the secure three-column fixation afforded by the screws, the superior control of the upper and lower instrumented vertebrae and the ability to manage larger scoliosis deformities with a posterior-only approach.3,4 In addition, a recently noted advantage is the realisation that three-column screw fixation of the periapical region of a scoliosis deformity can provide a mechanism for true apical derotation.

These recent advances in the safe and efficacious use of both thoracic and lumbar pedicle screw fixation in scoliotic vertebrae have consequently provided an opportunity for advancing 3D realignment of scoliosis through periapical derotation. As with any new principle, there are many techniques available to accomplish this periapical derotation. Utilising fixed-angle pedicle screws at the apex provided significantly more derotation effect than multiaxial screws because of the more direct relationship between screw derotation and vertebra derotation afforded by a fixed-angle screw.1 Active derotation manoeuvres, consisting of the manipulation of either concave apical screws pushed in a lateral direction or convex periapical screws pushed in a medial direction, may also accomplish periapical derotation. From a biomechanical perspective, it has been found that pushing and derotating a convex periapical pedicle screw provides a more effective and safer derotation manoeuvre than manipulating a concave periapical screw.6 The anatomical rationale stems from the knowledge that the medial pedicle border has stronger bone to be able to accommodate the force of a convex periapical screw derotation compared with the weaker lateral vertebral body bone. The position of the aorta on the left side of the thoracic vertebra also mandates careful consideration of unilateral concave periapical screw derotation for fear of displacing the concave tip of the pedicle screw outside of the vertebral body.

Triangulation of both concave and convex pedicle screws is a logical consideration in periapical screw derotation. This manoeuvre expands on the initial device for transverse traction (DTT), which linked both sides of the spinal construct together. This principle was also espoused over two decades ago by Daniel Chopin, with the knowledge that triangulated lumbar pedicle screws were extremely resistant to dorsal pull-out forces compared with non-linked pedicle screws. Based on this biomechanical and clinical foundation, the vertebral column manipulator (VCM) device was developed.

The basic theoretical procedure behind the VCM device is to initially triangulate periapical pedicle screws, then link these triangulated screw constructs together into a ‘quadrilateral’ frame for maximum periapical pedicle screw capture, control and stress distribution. Intuitively, greater numbers of periapical pedicle screws captured and cohesively manipulated will decrease the stresses on individual bone–screw interfaces. This principle has been validated in a biomechanical cadaver study by Cheng and colleagues.7 They found an increasing degree of overall device stability with decreasing degrees of bone–screw interface loosening, going from manipulation of a single periapical pedicle screw, to a unilateral linked system, to a triangulated system, to a quadrilateral frame mechanism as provided by the VCM device.

The components of the VCM instruments consist of a derotator implant holder that attaches to the side wall of a fixed or multiaxial LEGACY™ pedicle screw, a derotator bridge that connects to the derotator implant holder with a derotator bridge nut and derotator bridge handles that
DEFORMITY SOLUTIONS

The CD HORIZON® LEGACY™ Spinal System and its Vertebral Column Manipulation (VCM) Instrument Set can be used in scoliotic deformity cases where segmental CD HORIZON® LEGACY™ Spinal System pedicle screw purchase has been performed.

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can be joined together with derotator interlinks. Assembly of this system begins by attaching the derotator implant holder onto the medial tabs of the LEGACY pedicle screw by squeezing the open lever. Concave and convex screws on an individual vertebra are then joined by attaching the pre-loaded bridge nut to the cephalad portion of the derotator implant holders. The attachment is then secured by tightening the derotator bridge nuts bilaterally. In a very small, flexible deformity, this single-level triangulated derotation device can be utilised by attaching both the superior and convex bridge handles to allow active derotational manipulation of this vertebra during application of the concave correcting rod.

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However, more commonly a quadrilateral frame of four, five or six derotation implant holders will be applied to two or three periapical vertebrae. Once all three concave and convex screws are triangulated, a quadrilateral frame is produced by placing the interlink devices onto the superior and convex handles, respectively. By tightening the interlink nuts onto the handles, a secure quadrilateral frame is then produced, which resembles an external fixator device. Accordingly, manipulation of the entire VCM assembly allows for a maximum degree of derotation force to be safely applied to the periapical region. Torque measurements in excess of 100–120Nm have been safely applied in vivo during thoracic, thoracolumbar and lumbar derotation procedures. Obviously, one must always monitor the bone–screw interface while performing these types of manoeuvres, but in idiopathic scoliosis this device will typically maintain secure attachment to the vertebrae because of its multilevel capture affording multilevel bone–screw stress distribution.

Although there are a variety of correction techniques available when utilising the VCM device, one of the most common is concave rod application with active VCM manipulation occurring prior to apical screw–rod capture. In this manoeuvre, the sagittal plane pre-bent concave rod is engaged into the cephalad pedicle screws, then rotated into the distal screws, which are captured when the sagittal rod orientation is appropriate for overall sagittal plane alignment. Next, with continued derotation and translational forces applied by the VCM device, the apex of the rod is engaged into the saddle of the pedicle screws by an end-to-periapical capture mechanism utilising a pericapical rocker blocker and/or a Beale saddle. In a larger scoliotic deformity, a single apical, concave, multiaxial reduction screw (MARS) will aid this pericapical rod capture. In this manoeuvre, a single concave MARS will not have a VCM derotation implant holder attached, but the pericapical concave and convex and corresponding apical convex screw will.

Once the VCM quadrilateral frame is configured, manipulation of the device can result in several modes of correction. Manipulation of the convex handles in a ventral fashion will provide a pure apical vertebral derotation manoeuvre. Corresponding manipulation of the superior handles may also aid in reduction of the concave apical lordotic deformity. Simultaneous to this type of derotation manoeuvring, translational forces may be applied to the device as well as the chest wall for medialisation of the apex of the deformity towards the concave correcting rod. There is much versatility afforded by this system, all with the built-in application of multilevel screw capture and stress distribution. The net effect is optimal apical derotation and its positive influence on thoracic and lumbar prominence,8,9 as well as on pulmonary function.10

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Since the introduction of the CD instrumentation 25 years ago, the quest for optimal 3D scoliosis correction has continued. We believe the combination of pericapical thoracic pedicle screws undergoing a bilateral apical vertebral derotation (BAVD) technique utilising the VCM instrument set is the next step in the evolution of the CD philosophy. The VCM device provides not only optimal pericapical vertebral manipulation, but also marked correlative correction of the thoracic and lumbar rib prominence. None of these continuing advances would have been possible without the initial foresight, innovation and theories introduced by Drs Yves Cotrel and Jean Dubousset 25 years ago, which forever changed the surgical correction of scoliotic deformities.