Eur Spine J
DOI 10.1007/s00586-016-4561-x

IDEAS AND TECHNICAL INNOVATIONS

The use of a pedicle screw–cortical screw hybrid system for the surgical treatment of a patient with congenital multilevel spinal non-segmentation defect and spinal column deformity: a technical note

Kimberly Ashayeri[1] · Rani Nasser[1] · Jonathan Nakhla[1] · Reza Yassari[1]

Received: 27 July 2015 / Revised: 31 March 2016 / Accepted: 1 April 2016

Abstract
Introduction This technical note presents, to the authors' knowledge, the first reported case of a hybrid pedicle-cortical screw system for instrumented fusion in a patient with congenital vertebral column deformity.
Case Cortical screws were navigated using stereotactic guidance to extend a prior non-segmented fusion mass, facilitating instrumentation in a circumstance with completely distorted anatomy. This technique provided a safe trajectory with excellent cortical purchase in an anatomically deformed spine.
Discussion Cortical screw fixation may serve to be helpful in augmenting pedicle screw fixation and in circumstances in which the bone quality is suboptimal or the pedicles are compromised. Cortical screw fixation is a relatively new technology, but it may prove to be invaluable in providing an adjunct to pedicle screw constructs in anatomically distorted or osteoporotic spines.

Keywords Cortical screw · Pedicle screw · Spinal column deformity · O-arm stereotactic navigation

Introduction

The introduction of pedicle screw instrumentation in 1984 by Roy-Camille has greatly increased the success rate for fusion and stabilization in the lumbar spine with a mean fusion rate of 93 % [1, 2]. A more recent approach for instrumented stabilization is cortical screw placement: They function to maximize the amount of cortical bone in the screw trajectory when compared to pedicle screws. Several studies have examined the biomechanics of cortical screw fixation on cadaveric specimens and have demonstrated a 1.71 times higher torque strength in cortical screws, an indicator of good cortical purchase [3, 4]. The bicortical purchase of cortical screws provides a stronger purchase and demonstrated a 30 % increase in uniaxial yield pullout strength as compared to pedicle screws [5, 6]. In addition, the screw trajectory offers a 100 % increase in interface strength per unit screw length due to the denser juxtaposed osseous tissue with a smaller screw length [5].

One such instance of unique anatomy is presented in this case report: It constitutes, to the authors' knowledge, the first reported case of a hybrid pedicle–cortical screw system for instrumented fusion in a patient with congenital vertebral column deformity.

Case report

History and presentation

This 68-year-old man presented with progressively worsening gait and balance problems. Two weeks prior he developed urinary and fecal incontinence and was unable to move his legs. He was complaining of severe back pain and difficulties controlling his legs due to severe spasm. At the age of 6 months, he underwent spinal surgery when, according to the patient, his "mother's bone was used to fix the spine." On examination he was 2/5 motor function in both lower extremities and he had sensory level at T10. His rectal tone was decreased with severe spasticity, bilaterally

✉ Kimberly Ashayeri
kimberly.ashayeri@med.einstein.yu.edu;
kimberly.ashayeri@gmail.com

[1] Department of Neurosurgery, Albert Einstein College of Medicine and Montefiore Medical Center, 3316 Rochambaeu Avenue, Bronx, NY 10467, USA

Published online: 02 May 2016

present Babinsky's sign, and clonus. The patient had no evidence of motor or sensory deficits in the upper extremities.

Imaging studies

Magnetic resonance imaging and CT scan of the cervical, thoracic and lumbar spine demonstrated congenital non-segmentation of C3 and C4 and partial non-segmentation of C5 with underdeveloped intervertebral disk at C4–5 (Fig. 1a). Counting down with the cervical spine as reference, there was severe spinal canal stenosis at T8–9 and T9-10 with a vacuum sign in the disk space and an ossified disk herniation toward the right side at T7–8 (Fig. 1b). At that level there was cord compression, signs of myelomalacia and cord edema. Only ten thoracic vertebrae were identified, and L5 was sacralized. Between T7–8 and L5 there was a large block vertebra with a large posterolateral fusion mass. The block vertebra consisted of anatomically identified thoracic and lumbar vertebrae that corresponded to the thoraco-lumbar junction (Fig. 2). The conus medullaris was within the normal anatomic position based on the counting algorithm, and there was no fatty filum or tethering of the spinal cord visible. Based on his clinical and radiographic findings, we recommended a T8–9 transpedicular discectomy, T9–T10 laminectomy and fusion from T6 to L2 (Fig. 4.).

Operation

The patient was taken to the operating room and positioned prone on an open Jackson table. The incision was planned over the previous midline incision site extending cephalad

Fig. 2 Block vertebra. Computer tomography (*left*) and MRI (*right*) of block vertebrae at the thoraco-lumbar junction. There is a vacuum sign visible at T9–10

and caudal for adequate exposure. After exposure, an intraoperative stereotactic CT was performed, with fixated hip pin in the iliac crest as a navigation reference frame. Intraoperative navigation was especially helpful with localizing the T7/T8 level, where the transpedicular discectomy was performed. Once the anterior compressive elements were successfully removed, we proceeded with a

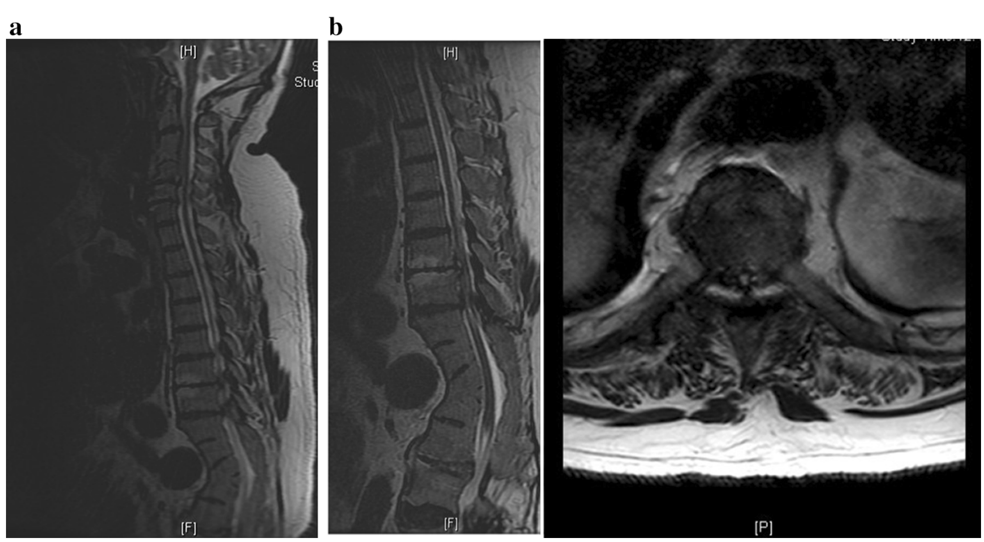

Fig. 1 a MRI demonstrating congenital deformity with subsequent stenosis. **a** Sagittal MRI showing abnormalities in the cervical, thoracic and lumbar spine. **b** *Left* Sagittal MRI of thoracic spine with spinal canal stenosis at T8–9 and T9–10 and blocked lumbar spine distorting spinal anatomy. *Right* Axial MRI indicating severe spinal stenosis at T6–7

laminectomy from T8 to T10 using a high-speed 6-mm coarse diamonds drill bit. After adequate decompression, pedicle screws were placed with the assistance of stereotactic navigation at T6 and T7 on the right and T6–T8 on the left (Fig. 3.). We then turned our attention to the area of the posterior lateral fusion at the level of the block vertebra. Cortical screws were placed with stereotactic navigation to maximize the cortical fixation within the fusion mass (Fig. 4.). This proved especially challenging because of the underlying congenital malformation of the spinal column as well as the underdeveloped pedicular system. Instrumented arthrodesis was performed from T6 to L2 with the placement of a cross-link to connect the pedicular–cortical screw hybrid stabilization system (Fig. 3).

Postoperative course

The patient had a slow recovery with considerable improvement of the motor strength in both legs at 6-month follow-up, although he was not ambulatory. He was able to void spontaneously and no longer required intermittent catheterization.

Discussion

The landscape of spinal instrumentation has dramatically changed over the past 50 years. Spinal fixation with pedicle screws evolved from its limited use for fracture treatment starting in 1963 to its current use as internal fixation to correct instabilities of the spine. Although pedicle screw fixation has become the present day gold standard, it also has some limitations: A recent study indicates an overall complication rate of 17.8 % in thoraco-lumbar spine fixation [7, 8]. Another limitation of pedicle screw fixation includes their use in patients with osteoporosis or osteopenia. Approximately 44 million Americans have osteoporosis, which may weaken the pedicle screw purchase in the vertebral body [7, 9]. Finally, oncological invasion of the bone, infectious erosive changes and deformity cases with no clearly delineated anatomy including congenital deformities with abnormal vertebral anatomy may affect pedicle screw purchase.

Fig. 3 Hybrid fixation system. Postoperative CT scan showing positioning of pedicle screw–cortical screw hybrid fixation system

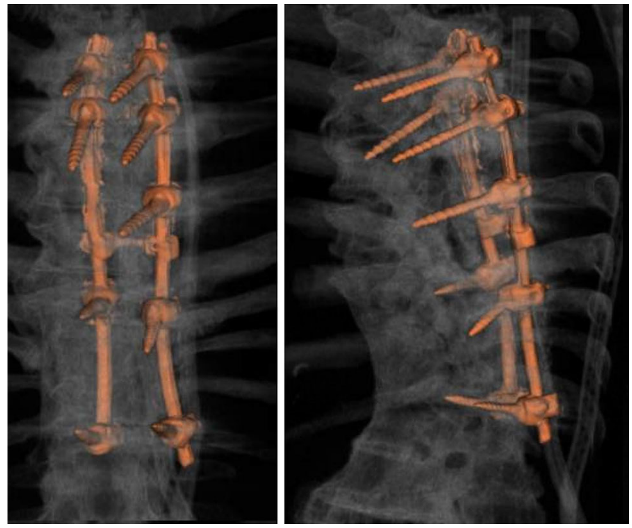

Fig. 4 3D reconstruction of hybrid cortical screw system. 3D reconstruction of the construct: *right* T6/T7 pedicle screws, *left* T6/T7/T8 pedicle screws and cortical screws inferior to the spondylotic areas bilaterally

Prior to pedicle screw fixation, laminar hooks and wiring were also widely used instrumentation in spinal fusion. Laminar hooks could provide cortical fixation and may be beneficial in instances of osteopenia and osteoporosis [10]. However, the biomechanical pullout strength of pedicle screws has been shown to be stronger than laminar hooks, wires or tape [11]. The three-column fixation of pedicle screws has been shown to be stronger, even when compared to smaller thoracic pedicles [10]. For these reasons, the use of hooks has decreased considerably, replaced by a pedicular fixation system. Cortical screws have evolved as a method of spinal instrumentation that may avoid some of the limitations of pedicle screw fixation. Cortical screws are inserted in a caudocephalad path and are directed laterally in the transverse plane, "engaging only cortical bone in the pedicle without the involvement of the vertebral body trabecular space" [1, 5]. On CT scan analysis of the density of bone in the region of screw insertion, it was found that cortical screws involved bone with density four times higher than that for traditional trajectory [12]. Avoiding the trabecular portion of the pedicle increases the overall strength of the screw. This can be particularly important in patients with severe osteoporosis. Ueno et al. reported such a patient who underwent deformity correction with a multilevel pedicle screw instrumented fusion that was reinforced at each level with bilateral cortical screw placement in series with the pedicle screws [13]. As the authors admit, there are some issues with such a construct from an economic perspective and length of surgery. In addition, the superiority of a dual fixation system over a single system (cortical or pedicle screw system alone) has not been demonstrated biomechanically. Additionally, cortical screws have been successfully used for previously instrumented pedicles using CT guidance [14, 15]. The feasibility of the use of a hybrid system has also been shown in anatomically intact, non-osteoporotic spines. Takata used a dual-hybrid system to correct degenerative lumbar spondylolisthesis in six patients [16]. The failure rate and progression of the slippage are minimal in this patient series; however, the study only has a follow-up period of 3 months.

The use of cortical screws to augment and extend a prior non-segmented fusions mass has proven invaluable to use in our case report. We combined the two systems in series with pedicle screw fixation over the cephalad portion and the use of a cortical screw system over the caudal portion where the anatomy was completely distorted due to the previous surgery and the presence of a block vertebra spanning an estimated four levels with a massive posterior fusion mass, aberrant anatomy and hypoplasia of the pedicles. The size of the pedicle did not allow for placement of pedicle screws even with the use of stereotactic guidance. Although the congenital deformity and prior fusion mass bone quality were suboptimal, we believe that the best fixation modality was the use of navigated cortical screws to maximize the purchase into sclerotic bone (as compared to laminar wires, hooks and tape). Moreover, the cortical screw purchase was intraoperatively confirmed by the audibly strong bites placing the screw as well as pulling on the screw after placement. Under those circumstances, the use of cortical screws provided a safe trajectory with excellent cortical purchase. The use of the stereotactic navigation was not only extremely beneficial but in this case mandatory since there were no clear landmarks for the placement of the screws, given the prior fusion mass. Thus, we were able to stabilize the patient's spine with a robust and stable hybrid instrumented fusion system while avoiding injury to the neural elements in an otherwise complicated anatomy. The use of a hybrid pedicle–cortical screw instrumentation system may also be of value in revision surgery where the pedicles may be compromised or when bone quality is suboptimal.

Acknowledgments No funding or grants.

Compliance with ethical standards

Conflict of interest None of the authors has any potential conflict of interest.

References

1. Roy-Camille R (1986) Plating of thoracic, thoracolumbar, and lumbar injuries with pedicle screw plates. Orthop Clin N Am 17:147–159
2. Lee GW (2015) The comparison of pedicle screw and cortical screw in posterior lumbar interbody fusion: a prospective randomized noninferiority trial. Spine J 15:1519–1526. doi:10.1016/j.spinee.2015.02.038
3. Mishiro T (2014) Assessment of maximal insertional torque of cervical and thoracic screws during posterior spinal surgery. J Med Investig JMI 61:393–398
4. Wray S (2015) Pedicle screw placement in the lumbar spine: effect of trajectory and screw design on acute biomechanical purchase. J Neurosurg Spine 22:503–510. doi:10.3171/2014.10.SPINE14205
5. Santoni B, Hynes R, McGilvray K, Rodriguez-Canessa G, Lyons A, Henson M, Womack W, Puttlitz C (2009) Cortical bone trajectory for lumbar pedicle screws. Spine J 9:366–373
6. Ueno M (2015) Should we use cortical bone screws for cortical bone trajectory? J Neurosurg Spine 22:416–421. doi:10.3171/2014.9.SPINE1484
7. Perez-Orribo L (2013) Biomechanics of lumbar cortical screw-rod fixation versus pedicle screw-rod fixation with and without interbody support. Spine (Philadelphia, Pa 1976) 38:635–641. doi:10.1097/BRS.0b013e318279a95e
8. Nasser R, Yadla S, Maltenfort MG, Harrop JS, Anderson DG, Vaccaro AR, Sharan AD, Ratliff JK (2010) Complications in spine surgery. J Neurosurg Spine 13:144–157. doi:10.3171/2010.3.spine09369
9. Boos N, Webb JK (1997) Pedicle screw fixation in spinal disorders: a European view. Eur Spine J Off Publ Eur Spine Soc Eur Spinal Deform Soc Eur Sect Cerv Spine Res Soc 6:2–18
10. Cordista A, Conrad B, Horodyski M, Walters S, Rechtine G (2006) Biomechanical evaluation of pedicle screws versus pedicle and laminar hooks in the thoracic spine. Spine J Off J N Am Spine Soc 6:444–449. doi:10.1016/j.spinee.2005.08.015
11. Liljenqvist U, Hackenberg L, Link T, Halm H (2001) Pullout strength of pedicle screws versus pedicle and laminar hooks in the thoracic spine. Acta Orthop Belg 67:157–163
12. Kojima K (2015) Cortical bone trajectory and traditional trajectory—a radiological evaluation of screw-bone contact. Acta Neurochir (Wien). doi:10.1007/s00701-015-2432-6
13. Ueno M, Imura T, Inoue G, Takaso M (2013) Posterior corrective fusion using a double-trajectory technique (cortical bone trajectory combined with traditional trajectory) for degenerative lumbar scoliosis with osteoporosis. J Neurosurg Spine 19:600–607. doi:10.3171/2013.7.SPINE13191
14. Rodriguez A, Neal MT, Liu A, Somasundaram A, Hsu W, Branch CL Jr (2014) Novel placement of cortical bone trajectory screws in previously instrumented pedicles for adjacent-segment lumbar disease using CT image-guided navigation. Neurosurg Focus 36:E9. doi:10.3171/2014.1.focus13521

15. Calvert GC (2015) Cortical screws used to rescue failed lumbar pedicle screw construct: a biomechanical analysis. J Neurosurg Spine 22:166–172. doi:10.3171/2014.10.SPINE14371

16. Takata Y (2014) Hybrid technique of cortical bone trajectory and pedicle screwing for minimally invasive spine reconstruction surgery: a technical note. J Med Invest 61:388–392