Editorial

Computed tomography and pedicle screws

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In this study by Bydon et al., the authors evaluated the accuracy and intraoperative revision rate of free-hand pedicle screw placement using an intraoperative CT scanner at a single academic neurosurgical spine practice. They concluded, “Compared with a similar cohort of patients from their institution who had pedicle screws inserted via the free-hand technique with postoperative CT, the authors found that the intraoperative CT lowers the threshold for pedicle screw revision, resulting in a statistically higher rate of screw revision in the thoracic and lumbar spine (p < 0.0001). During their 2.5-year experience with the intraoperative CT, the authors did not find a reduction in rates of reoperation for misplaced pedicle screws.” There are several points worthy of consideration in this paper.

The authors nicely demonstrate that the utilization of technology that provides real-time anatomical information will tap into our desire to try and achieve the best possible result (“perfection,” as noted by the authors). This behavioral change occurred despite experience from their previous publication that the majority of pedicle breaches do not lead to negative clinical results. It is intuitive that our intraoperative threshold for revising a less than ideally placed implant would be much lower compared with when we are faced with the same information postoperatively. In other words, faced with a misplaced screw on postoperative CT, without clinical sequelae or a reasonable likelihood of future sequelae from a misplaced screw, we are not likely to take a patient back for screw revision. Having had the opportunity to use intraoperative CT on a limited basis over the last 2 years, my experience and behavior certainly parallels that of the authors. However, the conclusion of this study brings to mind the famous quote from Voltaire, “perfect is the enemy of the good,” meaning that insisting on perfection often results in no improvement at all.

By all accounts, it would be reasonable to expect that the intraoperative modification of misplaced screws should translate to reduced clinical sequelae and therefore lead to a reduced reoperation rate. This is certainly the sensible argument to offset the initial capital and ongoing operating cost of such technology. In this study, however, the authors found no difference in reoperation rate. In one revision case, the clinically symptomatic screw was in fact a revised screw. In the second case, it was an excessively long screw that contacted the aorta following confirmation of a good trajectory dictated by placement of a marker. The common thread in both revision cases was a final scan after placement of all screws (including revised screws) would have mitigated both revisions. Thus, the reoperation rate was ultimately due to the clinical protocol and not the technology itself. However, multiple scans are not without risk due to radiation exposure to the patient and increased operative time. I would be critical that the authors did not discuss any change in their clinical protocols or propose a consensus practice at their institution going forward as result of this study. The authors also did not discuss the potential use of adjunctive technologies to improve on their screw revision rate and/or postoperative revision rate.

As I am a published proponent of using intraoperative imaging devices combined with navigation technologies, the following perspective on possible ways of improving the use of intraoperative CT scanning is biased, and I look forward to commentary from the authors. However, I will utilize the current literature to support my bias. In a recent meta-analysis, by Shin et al., the authors reported on 20 comparative studies using free-hand versus navigated (mostly 3D) techniques for pedicle screw placement. The authors noted a mean pedicle breach rate of 15% for free-hand versus 6% for navigated screws. Improved accuracy using navigation is well known; however, it does not eliminate the risk of pedicle breach. More importantly, this meta-analysis noted 3 screw-related neurological complications from 3725 screws compared with 0 from 4814 screws placed using navigation (data from 12 studies). There was no difference in operative time or estimated blood loss between groups. The overall mean postoperative screw revision rate (reported in 10 studies) was 2.0% for free-hand versus 1.4% for navigated screws (p = 0.11). The bottom line is that pedicle breaches are highly variable and relatively common. Breach rates can certainly be reduced or corrected by navigation and/or intraoperative CT; however, the rate of clinical sequelae and thus reoperation is rather low. Consequently, the value relative to the learning curve, expense, and increased operative times...
that are often associated with the use of navigation or intraoperative CT preclude widespread use of the technology if there is no meaningful reduction in the reoperation rate. Therefore, it would seem that the number of screws that need to be placed using navigation or redirected with intraoperative scans to save one revision is relatively high, and the cost-effectiveness of these technologies will remain a point of ongoing debate.

Growing evidence is suggesting that the combination of intraoperative 3D imaging combined with navigation may provide a potential solution, particularly for high-risk regions or complex anatomical challenges. In a recent study by Van de Kelft et al., the authors reported their initial experience with the use of intraoperative CT combined with navigation for the placement of 1922 pedicle screws.4 In that study the authors noted a misplacement rate of 2.5% and an intraoperative revision rate of 1.8% of the screws compared with the 9% revision rate in the current study. The authors also noted that if the surgeon was confident in the screw position using clinical judgment (palpation of the pedicle track and correlation of the navigational system), the misplacement rate was 1% and they recommended that a second scan was not required in that scenario. In the present study, there was a very high intraoperative revision rate (35%) at the C-7 level. Pedicle screw placement at the cervicothoracic junction can certainly be challenging with highly variable anatomy most commonly occurring at C-7. In a study by Sugimoto et al., using an isocentric C-arm and navigation for placement of cervicothoracic junction screws, the authors placed 44 screws at C-7, with 3 pedicle breaches (all 2 mm or less) with no screw revisions.3

Given the findings of the current study, it would seem that the techniques described are inefficient (acknowledging that this is the authors’ early experience), and the authors should have provided suggestions for further improvement on their protocol. Although I am a proponent of the use of this technology, I would argue that these results warrant similar criticism that has been directed at the use of navigation to achieve the same purpose of reduced reoperation rates. In this study the authors note an additional 25 minutes to the total operative time for radiographic confirmation of screws after 1 intraoperative CT scan. However, there is no accounting of the additional time it took to revise screws, and the authors did not comment on the additional cost of wasting approximately 28 screws (based on information provided in the paper) to revise 103 screws. Clearly the cost-effectiveness of this or similar practices/techniques (including my own) need to be considered.

It is my firm belief that advances in intraoperative imaging technology and navigation will ultimately lead to improved patient safety. At present it seems that improved clinical, imaging, and navigational efficiency and continued efforts to reduce radiation exposure are required to eliminate reoperation due to pedicle screw misplacement. Furthermore, consensus regarding what is a clinically acceptable screw or implant position is also required to optimize limitations inherent to current technologies. (http://thejns.org/doi/abs/10.3171/2013.11.SPINE13891)

Disclosure

Dr. Rampersaud is a consultant for Medtronic and is on the advisory board for Medtronic–Surgical Navigation Technologies.

References


Response

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We would first like to express our sincere gratitude for the editorial written by Dr. Rampersaud. Dr. Rampersaud’s expertise in navigation techniques for the placement of pedicle screw instrumentation makes his commentary invaluable and provides insights into the role of intraoperative CT scanning in spinal instrumentation placement.

The objective of our clinical study was to describe our initial 31-month experience with the intraoperative CT scanner. While spine surgeons adopted this technology at our institution, the results of our initial experience do not suggest a reduction in rates of reoperation for misplaced screws. In response to Dr. Rampersaud’s concerns regarding the details of reoperation, 2 patients underwent reoperation for pedicle screw revision despite the use of the intraoperative CT scanner during the initial operation. In 1 case, the left L-3 pedicle screw was revised during the initial operation; however, a subsequent intraoperative CT scan was not obtained. In the second case, the CT scan was used with pedicle markers, prior to instrumentation placement. As in the first case, a confirmatory scan was not obtained. The screw that was placed after the CT scan was too long and extended into and compressed the wall of the aorta. Therefore, a subsequent revision procedure was required.

At our institution, surgeons utilize intraoperative CT scanning to confirm placement of either pedicle markers or pedicle screws, or both. In order to minimize operative time and radiation exposure to the patient, the frequency

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of scans in each case depends on the surgeon’s confidence in the pedicle screws’ trajectory and length.

While intraoperative CT imaging is increasingly utilized, radiography and fluoroscopy remain the modalities of choice for most spinal instrumentation cases. In fact, Dr. Rampersaud has published a well-designed clinical study on fluoroscopic guidance. Other technologies notwithstanding, CT scanning remains an important adjunct because of the superior visualization of the bony anatomy and the continuous imaging sequencing along the neural axis. While fluoroscopic guidance provides an adequate image of the screw trajectory, the identification of pedicle breaches is limited to the medial or lateral direction, as measured in the study by Rampersaud et al. The continuous axial slices on CT imaging provide the additional benefit of visualizing the craniocaudal trajectory of pedicle breaches, or approximately 20% of all breaches in our study. Lastly, although other publications mentioned by Dr. Rampersaud may underscore the accuracy of fluoroscopic guidance, these studies are limited to the thoracolumbar spine whereas our study found a statistically higher breach rate in the cervical spine.

Dr. Rampersaud also mentions the additional costs of wasting 28 screws in our series. However, we wish to clarify that per our results only 8 screws were “wasted”; 4 were removed without replacement and 4 were removed with replacement. In analyzing the results of this study, we did find that there were a number of intraoperative revisions performed for screws that were imperfectly placed, but they likely would have been clinically acceptable had they been detected on postoperative imaging. As Dr. Rampersaud noted, this served as evidence for Voltaire’s maxim, “perfection is the enemy of good.”

The results of this single institution study demonstrate that when compared with the free-hand technique, intraoperative CT scanning does not change the rate of take-back surgery for screw revision. As Dr. Rampersaud pointed out, adjustments could be made to our protocol that might enhance the efficacy of intraoperative CT imaging. It could be recommended that intraoperative CT scanning be used only after the instrumentation is placed, rather than with markers. Under this protocol, a follow-up scan would then be performed for any screw requiring revision. However, such a protocol would have to be weighed against the added risks of increased radiation exposure and increased operative time that would result from obtaining multiple intraoperative scans. Our hope is that our study on intraoperative CT can herald future prospective trials on the utility of this technology in spine surgery.

References


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