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CORR Insights®: Increased Radiation but No Benefits in Pedicle Screw Accuracy With Navigation versus a Freehand Technique in Scoliosis Surgery

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Where Are We Now?

Urbanski and colleagues [12] performed a retrospective study comparing CT-based navigation and a freehand technique of pedicle screw insertion in patients undergoing surgery for moderate idiopathic scoliosis. They concluded there were no benefits of CT-based navigated pedicle screw placement, but the patients who underwent CT-based screw placement received greater exposure to radiation. This study helps contextualize two important aspects of CT-based navigation for pedicle screw insertion: (1) Screw placement accuracy and (2) radiation exposure to the patient.

In a meta-analysis comparing the accuracy of pedicle screw placement in groups with and without navigation in both clinical and cadaveric studies [4], navigation provided a higher accuracy in screw placements for most of the subgroups presented, except at the thoracic levels, where there was no advantage. Kraus and colleagues [5] analyzed 2003 pedicle screw placements and found computer navigated procedures tended to be superior in the lumbar spine while conventional procedures were superior in the thoracic spine. The patient populations described in these studies were adults with various spinal disorders not limited to scoliosis.

Studies on patients with pediatric spinal deformity generally have reported superior screw placement accuracy and lower intraoperative screw revision rates with navigation [1, 8, 11]. In a study of 40 consecutive patients with idiopathic scoliosis, pedicle violation was observed in 11% of the navigation group and 28% of the control group [8]. Ughwanogho and colleagues [11] reported unsafe breach rates of 3% and 9%, and screw change rates of 0.6% and 5% in CT-navigated and freehand techniques, respectively in patients with adolescent idiopathic scoliosis. In a study of adult and pediatric patients with scoliosis and kyphosis [1], pedicle breach and revision rates were lower in the thoracic spine with CT navigation while there was no difference between the navigation and non-navigation groups for lumbar screw placement and revision. One patient had cerebrospinal fluid leak due to implant malposition in the non-navigation group in this series.

Overall, the accuracy of screw placement in scoliosis surgery using navigation has been estimated to range from 89% to 97%. At the same time, the accuracy of freehand pedicle screw placement in adolescent idiopathic scoliosis has been reported to range from 75% to 99% [6]. It would not be surprising that high freehand accuracy in a population subset could negate the accuracy benefits from CT navigation.

The high radiation exposure to the patient is area of concern when using CT navigation. The radiation dose during pedicle screw placement using intraoperative CT navigation

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versus fluoroscopy in children with idiopathic scoliosis was reported to be four times greater in CT navigation, even with low-dose scans [7, 10]. In one study, patients in the CT group who are obese had the highest effective dose, ranging from 3 to 8.5 mSv [7]. Recently, patients who had serial radiographs during treatment 25 years previously for adolescent idiopathic scoliosis were found to have an overall cancer rate five times higher than the age-matched local population [9]. An average of 16 radiographs were taken during the treatment period, with a mean total radiation exposure of 2.4 to 5.6 mSv/year. The findings on increased cancer risk still need validation from other studies, but we should be aware that the total radiation exposure reported during the treatment period could be exceeded in one CT-navigation surgery, based on the radiation dose reported in the present study [12].

Where Do We Need To Go?

There is considerable variation in the accuracy of navigated pedicle screw placement in prior studies; this likely is a function of inconsistencies in methods used to assess pedicle breach, patient populations, spinal pathology, and the region of instrumentation [1, 4, 5, 8, 11, 12]. Therefore, a first step might be to standardize our approach to assessing whether the pedicle has been breached. Thirty-five different assessment methods were found in a meta-analysis about the accuracy of pedicle screw placement [4]. The present study used an assessment based on that of Gertzbein and Robbins, identifying properly positioned screws as those in Grades 0 and 1, and misplaced screws as Grades 2 and 3 [3]. However, in their paper, Gertzbein and Robbins also identified a safe zone of 0 mm to 4 mm in relation to intradural contents and expressed concern over screws that were inserted with > 4 mm encroachment (Grade 3) in eight patients, two of whom had minor neurological symptoms. The present study had four pedicle breaches of > 4 mm in the upper thoracic spine in the freehand group compared to none in the navigation group. All four screws were immediately repositioned. Urbanski and colleagues could have benefited from navigated screws had they used the "safe" (Grades 0-2) and "unsafe" (Grade 3) groupings in relation to intradural contents.

Do lower accuracy rates in freehand versus navigated screw placement translate into clinical problems for patients? Poorly placed screws may not need revision, and the utility of navigated screw placement to reduce the chance of catastrophic screw malposition is unclear given the low revision and symptomatic misplaced freehand screw rates of 0.6% and 0.14%, respectively [2]. We need more information on the clinical advantage of the higher accuracy of navigated over freehand screw placements.

The lack of stratification according to age, region of the spine, curve size, and pedicle morphology limits the usefulness of a study. Studies with broad age ranges that include small children and adults are subject to inconsistencies in screw placement accuracy due to the large difference in the size of the pedicles.

We need to determine the accuracy advantage of navigation over freehand screw placement in scoliosis surgery using randomized studies that focus on tight age ranges, curve magnitudes, and defined pedicle morphologies. This could in turn help reduce radiation exposure to the patient by limiting the use of CT navigation to specific pathologies or spinal regions. The development of even lower dose CT protocols is needed to further reduce radiation exposure to the patient.

How Do We Get There?

Inconsistencies in the reported accuracy of image-guided navigational systems over freehand techniques reflect the need for more focused research. These studies should be stratified based on age group, separating small children, adolescents, and adults; the type and the magnitude of the deformity; pedicle morphology; and the experience of the surgeon. A common pedicle breach classification based on spinal canal encroachment should be used as well. Radiation doses to the patient should be reported in all studies using navigation. Clinical studies to validate the efficacy of low-dose CT scans for intraoperative navigation are needed. Can technological advances reduce the radiation dose from CT scans even further?

The evidence to date supports higher accuracy of pedicle screw placement using CT-based navigation compared to freehand techniques. The challenge is determining whether the higher accuracy is clinically important, and whether it justifies the equipment cost, and more importantly, the increased radiation exposure to pediatric patients.

Presently, CT-based navigation may not offer an advantage for experienced surgeons placing pedicle screws in patients with mild to moderate scoliosis, where freehand accuracy is high. However, it may be of value in patients with small or dysplastic pedicles, congenital abnormalities, or severe deformities. Clear evidence of its benefit in these areas is needed for surgeons to decide whether the increased radiation exposure to patients is justified.

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