# Robotic-Assisted and Computer-Assisted Navigation in Posterior Spinal Fusion for Idiopathic Scoliosis is Associated with Decreased Intraoperative Radiation Dose but Increased Overall Cumulative Dose Compared to Freehand Technique

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INTRODUCTION:

Computer-assisted navigation (NAV) and robotic-assisted navigation (RAN) for pedicle screw placement in posterior spinal fusion (PSF) of patients with idiopathic scoliosis (IS) have been increasingly adopted over the freehand technique (FH) due to enhanced accuracy. However, both RAN and NAV require either intraoperative three-dimensional imaging or preoperative computed tomography (CT), in addition to intraoperative fluoroscopy for checking safe screw placement. Both patients with idiopathic scoliosis and spine surgeons experience high radiation burdens and higher rates of cancer than the general population, making reduction in radiation exposure a key safety concern. The objective of this study was to compare mean intraoperative fluoroscopy time, fluoroscopy radiation dosage, and total radiation dosage (including preoperative CT) for RAN, NAV, and FH.

METHODS:

133 patients who underwent PSF for IS (41 FH, 12 NAV, and 80 RAN) were included. Patients were excluded if they were not between the age of 10 and 21 and if they did not have a primary PSF or available radiation dosing reports. The mean age was 14.8 years (range, 10.0 to 20.0), the mean body mass index (BMI) was 21.8 (range, 14.0 to 40.7), and 66.7% of patients were female. Patients underwent FH pedicle screw placement with fluoroscopy assistance, NAV using CT-guided navigation (FLASH, 7D Surgical) that utilized a preoperative CT, or RAN (Mazor, Medtronic), using a preoperative CT and fluoroscopy-to-CT registration intraoperatively. All preoperative CTs (for NAV and RAN) were obtained using the recommended CT protocol provided by the robotic company. All cases had routine use of fluoroscopy to check screws once placed and patient alignment during the correction. The mean fluoroscopy time in seconds, fluoroscopy radiation dose in millisieverts (mSv), and total radiation dose (including preoperative CT and intraoperative fluoroscopy) in mSv were compared by one-way analysis of covariance among the cohorts followed by pairwise comparisons, controlling for preoperative curve, BMI, and number of levels fused. Significance was set at an alpha of 0.05.

RESULTS:

The mean fluoroscopy effective dose was 0.494 ± 0.18, 0.263 ± 0.127, and 0.373 ± 0.103 mSv for FH, NAV, and RAN, respectively. NAV and RAN had a significantly lower fluoroscopy dosage than FH (both $p<0.001$), and NAV had a significantly lower fluoroscopy dosage than RAN ($p = 0.047$). When including preoperative CT, however, the mean cumulative effective radiation doses for FH, NAV, and RAN were 0.494 ± 0.183, 11.603 ± 2.849, and 12.437 ± 4.722 mSv, respectively. FH had a significantly lower cumulative radiation dosage than RAN ($p < 0.001$) and NAV ($p < 0.001$). There was no difference in cumulative radiation dosage between RAN and NAV ($p = 1.00$).

DISCUSSION AND CONCLUSION:

In this series of PSF for IS, NAV and RAN were associated with a 2-fold and 1.5-fold decrease in intraoperative radiation, but a 22 to 25 times higher total radiation dosage compared to FH, respectively. This finding represents a potentially lower radiation exposure to the surgeon but higher exposure to the patient. One limitation of the study was the use of the RAN company's protocol for preoperative CT scans for NAV patients. However, the authors have recently implemented a low dose CT protocol for these patients that reduces the CT radiation burden by up to 10-fold without sacrificing image quality. As NAV and RAN become increasingly adopted, therefore, it is important to be aware of the cumulative radiation exposure to surgeons, patients, and the operating room staff and to take proper precautions and adapt practices when feasible. Additionally, it is important for surgeons to work with navigation companies to minimize the settings recommended for preoperative CT imaging.

Table 2: Comparison of Radiation Effective Dosing between FH, NAV, and RAN

| | FH (n=41) | NAV (n=12) | RAN (n=80) | p-value |
|---|---|---|---|---|
| Fluoroscopy time, mean ± SD (range), seconds | **66.45 ± 25.56 (17.0 - 114.5)** | 32.28 ± 7.77 (19.7 - 45.7) | 49.71 ± 13.78 (34.0 - 90.8) | < **0.001** |
| CT DLP, mean ± SD (range), mGy-cm | N/A | 722.05 ± 159.22 (455.34 - 1091.84) | 834.82 ± 319.06 (337.0-1839.89) | 0.234 |
| Fluoroscopy Effective Dose, mean ± SD (range), mSv | **0.494 ± 0.183 (0.133 - 0.835)** | 0.263 ± 0.127 (0.130 - 0.631) | 0.373 ± 0.103 (0.175 - 0.650) | < **0.001** |
| CT Effective Dose, mean ± SD (range), mSv | N/A | 11.34 ± 2.780 (8.66 - 16.37) | 12.06 ± 4.71 (5.16 - 25.93) | 1.000 |
| Total Effective Dose, mean ± SD (range), mSv | 0.494 ± 0.183 (0.133 - 0.835) | **11.603 ± 2.849 (8.946 - 17.000)** | **12.437 ± 4.722 (5.607 - 26.133)** | < **0.001** |

SD: standard deviation; mSv: milli Severts; CT: Computed tomography; DLP: Dose length product; FH: Freehand, NAV: computer-assisted Navigation; RAN: Robotic-assisted navigation. **Bold** represents significance, corresponding to whichever techniques have significantly greater values.

Table 1: Demographics

| | Freehand N = 41 | Computer-Assisted Navigation N = 12 | Robotic-Assisted Navigation N = 80 | p-value |
|---|---|---|---|---|
| Sex, n (%) | | | | |
| Male | 19 (46.3%) | 4 (33.3%) | 20 (25.0%) | p = 0.059 |
| Female | 22 (53.7%) | 8 (66.7%) | 60 (75.0%) | |
| Age, mean ± SD, years | 14.51 ± 2.03 | 15.33 ± 2.46 | 14.82 ± 2.61 | p = 0.566 |
| Number of Levels fused, mean ± SD | 12.07 ± 2.22 | 11.00 ± 3.13 | 12.340 ± 2.00 | p = 0.140 |
| BMI, mean ± SD | 22.11 ± 4.50 | 20.11 ± 4.52 | 21.98 ± 5.32 | p = 0.450 |
| Pre-operative curve, mean ± SD, degrees | 56.76 ± 8.80 | 57.83 ± 10.04 | 58.09 ± 8.67 | p = 0.733 |
| Time between CT and surgery, mean ± SD, days | N/A | 29.67 ± 47.44 | 54.55 ± 42.49 | – |
| Lenke Classification, n (%) | | | | p = 0.297 |
| 1 | 19 (46.3%) | 6 (50.0%) | 37 (46.3%) | |
| 2 | 7 (17.1%) | 3 (25.0%) | 14 (17.5%) | |
| 3 | 5 (12.2%) | 0 (0.0%) | 3 (3.8%) | |
| 4 | 0 (0.0%) | 1 (8.3%) | 3 (3.8%) | |
| 5 | 9 (22.0%) | 2 (16.7%) | 13 (16.3%) | |
| 6 | 1 (2.4%) | 0 (0.0%) | 10 (12.5%) | |