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Patient Radiation Exposure Associated With the Use of Computer Navigation During Spinal Fusion

ALAN W. REYNOLDS, FRANCES HITE PHILP, SACHIN GANDHI, GARY L. SCHMIDT

Department of Orthopaedic Surgery, Allegheny General Hospital, Pittsburgh, Pennsylvania

ABSTRACT

Background: Calibration of computer navigation for spinal fusion is most commonly conducted using either a preoperative computed tomography (CT) scan or intraoperative O-arm scanning. This study aimed to directly compare patient radiation exposure from intraoperative O-arm use for pedicle screw placement versus typical diagnostic lumbar spine CT studies.

Methods: A retrospective review of patients undergoing O-arm navigated lumbar spine fusion procedures was performed to record radiation exposure as the primary outcome, as well as surgical and demographic details. The same was done for a control group of patients undergoing lumbar spine CT scans.

Results: A total of 83 patients undergoing lumbar spine fusion with O-arm navigation were included, as well as 105 unique patients who underwent a lumbar spine CT. The 2 groups were similar in terms of average age (60.2 versus 60.5, $P = .90$), average height (170 cm versus 169 cm, $P = .50$), and average weight (92.6 kg versus 90.9 kg, $P = .62$). Dose-length product for O-arm navigated procedures was 798.3 mGy-cm and 924.2 mGy-cm for CT scans ($P = .064$). Subgroup analysis revealed 18 patients who had both an O-arm navigated surgery and a lumbar spine CT. In this group the average dose-length product for O-arm surgeries was 806.2 mGy-cm and 822.1 mGy-cm for CT scans ($P = .92$).

Conclusion: This study revealed no statistically or clinically significant differences between patient radiation exposure for O-arm operative navigation compared to lumbar spine CT.

Clinical Relevance: Given the similarity in radiation exposure, surgeons should rely on other factors to guide decision making in regard to mode of imaging for navigation. Knowledge of this comparison and total radiation exposure will also be useful for patient education and shared decision making in regard to navigated procedures.

Lumbar Spine

Keywords: lumbar fusion, navigation, radiation, spine, spine surgery, robotic

INTRODUCTION

Computer navigation has been increasingly adopted for hardware placement during spinal fusion.¹ Multiple studies have documented the high accuracy and safety of pedicle screw placement achieved when taking advantage of this technology.^{2,3}

Calibration of computer navigation for spinal fusion is most commonly conducted using either a preoperative computed tomography (CT) scan or intraoperative O-arm scanning. A patient's preoperative CT scan is loaded into the navigation system and then "point match" registering is done during surgery whereby navigated tools are touched to known intraoperative anatomic landmarks on the patient. These landmarks are then matched to the same points on the CT scan. Alternatively, an intraoperative O-arm scan is

performed and navigated tools are referenced from a fixed clamp in this scan to determine the spatial location of the tools.

Radiation doses delivered to the patient have generally been found to be higher in cases using O-arm scanning for pedicle screw placement, compared to cases using fluoroscopy.^{4–6} However, several studies have reported O-arm radiation doses to be comparable or slightly less than doses associated with an average diagnostic CT scan.^{7–11} More evidence is needed to define variations, if any exist, in the amount of radiation incurred via each of these modalities used in spinal fusion procedures. To this end, the goal of this retrospective study was to compare cumulative radiation exposure in patients undergoing spinal fusion utilizing O-arm navigation versus a typical lumbar CT scan.

METHODS

Eligible Population

This study was performed as a retrospective case-control investigation. All adult patients undergoing a lumbar spine fusion using O-arm navigation by a single, fellowship-trained, orthopedic spine surgeon from calendar years 2015 to 2018 were initially included in the study. Only patients with incomplete operative or radiology records were excluded. A control group consisting of 105 randomly selected patients undergoing a regular lumbar spine CT scan was also identified by review of radiology records.

Outcome Measures

The primary outcome measure was radiation dose as measured in dose-length product (DLP) for both O-arm navigated procedures and CT scans. Demographic and surgical details were also collected including age, sex, weight, body mass index (BMI), number of levels fused, and length of surgery.

Data Collection

All data were collected from the electronic medical record, including patient charts, operative reports, and radiology procedure details. Prior to data collection being performed, this study was reviewed and approved by the Institutional Review Board.

Statistical Methods

Data are expressed as mean and SD of the mean. For comparison of continuous variables, Student *t* tests were used. A *P* value of $\leq .05$ was considered statistically significant.

RESULTS

A total of 83 patients undergoing lumbar spine fusion with O-arm navigation were included, as well as 105 unique patients who underwent a lumbar spine CT. The 2 groups were similar in terms of average age (60.2 versus 60.5, *P* = .90), average height (170 cm versus 170 cm, *P* = .50), and average weight (92.6 kg versus 90.5 kg, *P* = .62). Average DLP for O-arm navigated procedures was 798.3 mGy-cm and 924.2 mGy-cm for CT scans (*P* = .064). A summary of these data are presented in Table 1.

Table 1. Demographic information and radiation exposure for patients undergoing O-arm navigated lumbar spine fusion versus patients with lumbar computed tomography (CT) scan.

	O-Arm Group, mean \pm SD, n = 83	Lumbar CT Group, mean \pm SD, n = 105	<i>P</i> value (<i>t</i> test)
Age	60.2 \pm 12.8	60.5 \pm 17.5	.90
Height (cm)	170.0 \pm 10	169.0 \pm 10	.50
Weight (kg)	92.6 \pm 21.4	90.9 \pm 24.4	.62
BMI	32.0 \pm 6.8	31.5 \pm 7.7	.64
DLP (mGy-cm)	798.3 \pm 336.5	924.2 \pm 536.7	.064

Abbreviations: BMI, body mass index; DLP, dose-length product; mGy-cm, milligray-centimeter.

Subgroup analysis revealed 18 patients who had both an O-arm navigated surgery and a lumbar spine CT. In this group the average DLP for O-arm surgeries was 806.2 mGy-cm and 822.1 mGy-cm for CT scans (*P* = .92), as shown in Table 2.

DISCUSSION

This study was successful in comparing patient radiation exposure for O-arm navigated lumbar spine fusions and lumbar spine CT scans in 2 groups of subjects similar in age and body habitus. Our analysis found no statistically significant difference in radiation exposure between these 2 groups. It is notable, however, that the mean lumbar CT group exposure was higher and these results trended towards statistical significance for O-arm navigation resulting in less patient radiation exposure (*P* = .064).

A strength of this study is the subgroup analysis that was possible for 18 patients who had both an O-arm navigated procedure and lumbar spine CT, and thus were able to serve as their own controls. In this group there was again no statistically significant difference in radiation exposure. There was again a lower exposure for the O-arm but the difference was of lesser magnitude than in the complete study group.

Table 2. Subgroup of patients who underwent both an O-arm navigated lumbar spine fusion and a lumbar spine computed tomography (CT) scan.

	O-Arm Subgroup, mean \pm SD, n = 18	Lumbar CT Subgroup, mean \pm SD, n = 18	<i>P</i> value (<i>t</i> test)
Age	59.6 \pm 16.1	Same population	NA
Height (cm)	170 \pm 10.0	Same population	NA
Weight (kg)	94.4 \pm 19.2	Same population	NA
BMI	31.5 \pm 7.8	Same population	NA
DLP (mGy-cm)	806.2 \pm 437.7	822.1 \pm 526.1	0.92

Abbreviations: BMI, body mass index; DLP, dose-length product; mGy-cm, milligray-centimeter; NA, not applicable.

Spinal computer navigation may be referenced based off of a preoperative CT scan which is then “point matched” intraoperatively to known anatomic structures utilizing a navigated instrument. An alternative approach is to perform imaging on the table during the procedure (ie, an intraoperative spin with the O-arm) and then utilize these data for guidance during the surgery. One potential advantage to intraoperative imaging includes the maintenance of relationships between various anatomic structures, which potentially may differ in the supine position during a traditional CT scan. One potential disadvantage to this approach may be longer operative times given the extra step of obtaining the spin during the surgical procedure. In our study, intraoperative spins were used in all cases as per surgeon preference.

Although the results did approach statistical significance in the main study group, the clinical significance of this must also be considered. The total difference in mean radiation DLP between the 2 groups was 125.9 mGy-cm. In biologic effective dose equivalent units, the average radiation dose for O-arm navigation would be 14.3 millisieverts (mSv), compared to 14.6 mSv for a lumbar spine CT scan. Considering that an average pelvis x-ray equates to 0.6 mSv, we would argue that a difference of less than that value in terms of effective radiation dose is of limited clinical significance in this context.

The results of the present study are similar to the small number of previously published results on this topic. Most recently and most relevant was a study published by Balling et al which found average DLP for 306 O-arm navigated fusions to be 865.1 mGy-cm (798.3 mGy-cm in this study) and average DLP for 100 diagnostic lumbar CT scans to be 575.5 mGy-cm (924.2 mGy-cm for this study).⁹ A notable difference between the aforementioned study and our study is our noticeably higher DLP values observed for diagnostic CT scans, while the radiation exposure for O-arm navigation was very similar. The ultimate conclusion in the study by Balling et al was that O-arm navigation initially resulted in more radiation exposure to the patient; however, after a learning curve of 250 cases, the average DLP for O-arm cases was 562.1 mGy-cm, which was equivalent to their lumbar CT scans.

In a comparison of O-arm to intraoperative mobile CT (iCT-Airo), Scarone et al found an average radiation dose for 166 patients in the O-arm group of 19.12 mSv (versus 14.3 mSv in this

study).¹² The iCT-Airo group included 97 patients with an average exposure of 15.82 mSv. Other studies have found similar radiation exposure values for O-arm versus CT scan using dosimeter quantification and cadaveric models.^{6,7}

While this study considered radiation exposure to the patient only, exposure of the surgical team is also an important safety concern. At our institution the surgical team briefly leaves the operating room while the O-arm spins, meaning that there is no radiation exposure in this case. Previous studies have also documented less radiation exposure to the surgeon for pedicle screw placement using O-arm as opposed to C-arm.⁶

There are multiple limitations of this study, chief of which is that reported DLP represents an output of radiation and not a true measured dose received by various tissues within a patient. In addition to this, the control group included standard lumbar spine CT scans, and not navigation-protocol-directed scans, which could theoretically differ if they were intended to be used for calibration of intraoperative navigation. It would be of further use to study these comparisons more directly by independently measuring radiation exposure at various locations and comparing navigation-protocol CT scans.

CONCLUSION

Overall the study does provide a clinically useful estimate of radiation exposure from O-arm navigation for lumbar spine fusion compared to standard lumbar CT scans. Given the similarity in radiation exposure between O-arm navigation and lumbar CT scan, surgeons should rely on other factors to guide decision making in regard to mode of imaging for computer navigation. Knowledge of this comparison and total radiation exposure will also be useful for patient education and shared decision making in regard to navigated procedures.

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Disclosures and COI: Prior to data collection being performed, this study was reviewed and approved by the Institutional Review Board. The authors declare that there are no conflicts of interest.

Corresponding Author: Alan Reynolds, 1307 Federal Street, 2nd Floor, Pittsburgh, PA 15212. Phone: (412) 359-6501; Fax: (412) 359-6265; Email: Alan.reynolds@ahn.org.

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