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The Spine Journal 16 (2016) 343–354

THE SPINE JOURNAL

Clinical Study

Patient and surgeon radiation exposure during spinal instrumentation using intraoperative computed tomography-based navigation

Daniel Mendelsohn, MD[a,b], Jason Strelzow, MD[a,b], Nicolas Dea, MD[a,b], Nancy L. Ford, PhD[a,b], Juliet Batke, MSc[a,b], Andrew Pennington, MSc[a], Kaiyun Yang, MD[a], Tamir Ailon, MD[a], Michael Boyd, MD[a], Marcel Dvorak, MD[a,b], Brian Kwon, MD, PhD[a], Scott Paquette, MD[a], Charles Fisher, MD[a,b], John Street, MD, PhD[a,b,*]

[a]*Combined Neurosurgical and Orthopedic Spine Program, Vancouver General Hospital, Departments of Orthopedics and Neurosurgery, University of British Columbia, Vancouver, Canada*

[b]*Faculty of Dentistry, Department of Oral Biological and Medical Sciences, University of British Columbia, Vancouver, Canada*

Received 29 January 2015; revised 12 August 2015; accepted 10 November 2015

Abstract

BACKGROUND CONTEXT: Imaging modalities used to visualize spinal anatomy intraoperatively include X-ray studies, fluoroscopy, and computed tomography (CT). All of these emit ionizing radiation.

PURPOSE: Radiation emitted to the patient and the surgical team when performing surgeries using intraoperative CT-based spine navigation was compared.

STUDY DESIGN/SETTING: This is a retrospective cohort case-control study.

PATIENT SAMPLE: Seventy-three patients underwent CT-navigated spinal instrumentation and 73 matched controls underwent spinal instrumentation with conventional fluoroscopy.

OUTCOME MEASURES: Effective doses of radiation to the patient when the surgical team was inside and outside of the room were analyzed. The number of postoperative imaging investigations between navigated and non-navigated cases was compared.

METHODS: Intraoperative X-ray imaging, fluoroscopy, and CT dosages were recorded and standardized to effective doses. The number of postoperative imaging investigations was compared with the matched cohort of surgical cases. A literature review identified historical radiation exposure values for fluoroscopic-guided spinal instrumentation.

RESULTS: The 73 navigated operations involved an average of 5.44 levels of instrumentation. Thoracic and lumbar instrumentations had higher radiation emission from all modalities (CT, X-ray imaging, and fluoroscopy) compared with cervical cases (6.93 millisievert [mSv] vs. 2.34 mSv). Major deformity and degenerative cases involved more radiation emission than trauma or oncology cases (7.05 mSv vs. 4.20 mSv). On average, the total radiation dose to the patient was 8.7 times more than the radiation emitted when the surgical team was inside the operating room. Total radiation exposure to the patient was 2.77 times the values reported in the literature for thoracolumbar instrumentations performed without navigation. In comparison, the radiation emitted to the patient when the surgical team was inside the operating room was 2.50 lower than non-navigated thoracolumbar instrumentations. The average total radiation exposure to the patient was 5.69 mSv, a value less than a single routine lumbar CT scan (7.5 mSv). The average radiation exposure to the patient in the present study was approximately one quarter the recommended annual occupational radiation exposure. Navigation did not reduce the number of postoperative X-rays or CT scans obtained.

FDA device/drug status: Approved (O-arm intraoperative cone-beam CT).

Author disclosures: ***DM:*** Nothing to disclose. ***JS:*** Grant: Medtronic, F, Paid directly to institution/employer. ***ND:*** Nothing to disclose. ***NLF:*** Nothing to disclose. ***JB:*** Nothing to disclose. ***AP:*** Nothing to disclose. ***KY:*** Nothing to disclose. ***TA:*** Nothing to disclose. ***MB:*** Nothing to disclose. ***MD:*** Grant: Medtronic (F, Paid directly to institution/employer), outside the submitted work. ***BK:*** Nothing to disclose. ***SP:*** Nothing to disclose. ***CF:*** Grant: Medtronic (F, Paid directly to institution/employer), outside the submitted work. ***JS:*** Grant: Medtronic (F, Paid directly to institution/employer).

The disclosure key can be found on the Table of Contents and at www.TheSpineJournalOnline.com.

* Corresponding author. Blusson Spinal Cord Centre, 818 West 10th Ave, Vancouver, British Columbia, Canada V5Z 1M9. Tel.: +1-604-875-5328.

E-mail address: John.Street@vch.ca (J. Street)

http://dx.doi.org/10.1016/j.spinee.2015.11.020

1529-9430/

CONCLUSIONS: Intraoperative CT navigation increases the radiation exposure to the patient and reduces the radiation exposure to the surgeon when compared with values reported in the literature. Intraoperative CT navigation improves the accuracy of spine instrumentation with acceptable patient radiation exposure and reduced surgical team exposure. Surgeons should be aware of the implications of radiation exposure to both the patient and the surgical team when using intraoperative CT navigation.

Keywords: Complications; CT based navigation; Efficacy; Pedicle screw; Pedicle Screw Accuracy; Radiation exposure; Risk; Safety; Spine instrumentation; Spine navigation

Introduction

Intraoperative imaging in spine surgery is necessary for level verification, alignment visualization, guidance for implant placement, and bone removal. Conventional radiographs and fluoroscopy have been the mainstay of intraoperative spine imaging until the development of computer-assisted techniques [1]. Navigation technologies rely on the fixation of arrays with infrared visible points to a spinous process early on during surgical exposure and subsequent navigation of tools using an optical localizer. In two-dimensional fluoroscopic navigation, intraoperative Antero-Posterior (AP) and lateral X-rays are acquired and referenced to a preoperative computed tomography (CT) scan to enable navigation [2]. Isocentric three-dimensional (3D) fluoroscopic and intraoperative CT navigation techniques involve the acquisition of 3D images of the surgical field while the surgical team leaves the room or stands behind a lead shield, and thus is removed from radiation exposure [3,4]. The subsequent instrumentation of the spine with real-time multiplanar images using infrared optical guidance reduces the need for intraoperative X-rays or fluoroscopy [5].

Radiation-related complications of intraoperative fluoroscopy include skin erythema, cataract formation, thyroid cancer, and other malignancies [6]. Radiation exposure in spine surgery is 4 to 12 times higher than other orthopedic specialties, particularly so given the enhanced use of imaging during minimally invasive (MIS) and percutaneous surgical techniques [7–9]. Intraoperative exposure to radiation is of concern to both patients and the surgical team. Surgeons receive the highest radiation dose among members of the operative team from fluoroscopy because of their proximity to radiation scatter from the patient [10,11].

Pedicle screw malposition can cause dural tears and damage to neural, vascular, and visceral structures [12]. Navigation in spine surgery increases the accuracy of pedicle screw instrumentation and reduces malposition compared with freehand and conventional fluoroscopy techniques, which may improve patient safety [13–15]. However, there is little understanding as to how in real-life practice this technological shift is altering the radiation exposure to the surgical team and the patient.

The present study had three major goals. First, to compare the radiation exposure to the patient and the surgical team, we quantified radiation exposure from all intraoperative modalities (plain X-rays, fluoroscopy, and CT) during a cohort of cases navigated with intraoperative CT (O-arm, Medtronic, Minneapolis, MN, USA). Second, we quantified the radiation exposure during spine instrumentation using conventional fluoroscopy by performing a literature review. Third, we examined the impact of intraoperative CT navigation on the need for postoperative radiographs and CTs by including a matched comparison group of cases performed at our institution before the introduction of intraoperative CT navigation. The primary purpose of the present study was to determine the radiation exposure to the patient and the surgical team when using intraoperative CT navigation compared with non-navigated cases.

Materials and methods

Study population

We included patients who underwent a posterior spinal surgical approach for the insertion of pedicle instrumentation during which intraoperative cone-beam CT navigation (O-arm) was used either for navigated screw insertion or verification of pedicle screw placement at Vancouver General Hospital between January 1, 2012 and December 31, 2012. During the navigated cases, conventional fluoroscopy was also used to guide interbody device implantation and to visualize changes in alignment intraoperatively. A cohort of non-navigated patients who underwent posterior pedicle screw instrumentations between January 1, 2008 and December 31, 2008 before the introduction of O-arm at our institution were identified, and patients were selected based on the following matching criteria: age, gender, location of spinal surgery, and admitting diagnosis. All procedures were conducted by one of six fellowship-trained spine surgeons at a quaternary care academic teaching hospital. If interbody devices were implanted, they were placed through a posterolateral transforaminal lumbar interbody fusion approach. Patient demographics, admitting diagnosis, surgical procedure, spinal location of surgery, and the number of levels instrumented were prospectively recorded. Admitting diagnoses were categorized into trauma, tumor, major coronal deformity, degenerative (including spondylolisthesis), and revision of instrumentation. The study protocol was approved by both our hospital and the university research ethics boards. The present study was funded by an unrestricted investigator led grant of $100,000 from Medtronic paid entirely to the authors' academic institution.