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A 5-Year Retrospective Analysis of Exposure to Ionizing Radiation by Neurosurgery Residents in the Modern Era

Hasan A. Zaidi[1], Andrew Montoure[1], Peter Nakaji[1], Alden Bice[2], Luis M. Tumialán[1]

■ BACKGROUND: **The potential for radiation exposure during neurosurgical training has increased dramatically in the last decade. Incorporation of instrumented and minimally invasive spinal surgery and neuroendovascular procedures into the curriculum has led to increased potential for exposure to ionizing radiation. Contemporary neurosurgery residents' exposure to radiation has not been previously reported.**

■ OBJECTIVE: **To determine neurosurgery residents' exposure to radiation over the course of 7 years of training.**

■ METHODS: **Retrospective analysis of a prospectively maintained radiation database from July 2009 to July 2014 for all neurosurgery residents based on radiation dosimetry data. Standard radiation safety precautions were used (e.g., lead gowns or aprons), although compliance was not specifically monitored.**

■ RESULTS: **Thirty-eight neurosurgery residents were monitored from 2009 to 2014. Radiation exposure data were available for 34 residents for the final analysis. A total of 20,541 days of radiation monitoring data were available. The mean deep dose equivalent over this period was 0.67 ± 0.75 mrem per resident/day. The calculated maximum cumulative exposure during the course of residency training was 12.15 ± 13.50 mSv, approximately equivalent to 6 computed tomography head scans.**

■ CONCLUSIONS: **To our knowledge, this study is the first to quantify radiation exposure for neurosurgery residents in the current era of training. From this work, efforts may be initiated to increase awareness and safety with regard to radiation exposure. Although the total dose is not high, a better understanding of the impact of radiation exposure on practitioners may help to drive institutional policies to reduce occupational exposure.**

INTRODUCTION

The use of ionizing radiation for diagnostic purposes in the operating room has steadily increased over the past 2 decades,[1-3] and unintended radiation exposure for patients is increasing at a rate of 5% per year.[3] Although several authors have examined the amount of harmful radiation to the primary surgeon during various intraoperative procedures,[4-25] little attention has focused on the exposure risks of residents in training. The landscape of neurosurgical training has evolved dramatically in recent years, largely because of the emergence of minimally invasive spinal surgery[2,6,7,13] and neuroendovascular therapy[26] as integral parts of the training curriculum. Both of these modalities rely heavily on ionizing radiation for safe and efficient execution of various procedures. As a result, there has been a considerable increase in the amount of radiation to which trainees are exposed compared with past generations. The long-term sequelae of this radiation exposure by neurosurgery residents are unknown.

Although general practice guidelines are available from the Occupational Safety and Health Administration of the US Department of Labor and advisory committees such as the National Council of Radiation Protection and Measurements[27] and the International Commission on Radiological Protection, these guidelines are not specific to neurosurgery residents who are exposed to comparatively greater levels of radiation than

Key words
- Exposure
- Fluoroscopy
- Intraoperative
- Radiation
- Residency

Abbreviations and Acronyms
CT: Computed tomography
DDE: Deep dose equivalent
OEL: occupational exposure limit
OSL: optically stimulated luminescence

From the [1]Division of Neurological Surgery, Barrow Neurological Institute, and [2]Regulatory Compliance/Radiation, Safety Office, Corporate Compliance Department, St. Joseph's Hospital and Medical Center, Phoenix, Arizona

To whom correspondence should be addressed: Luis M. Tumialán, M.D. [E-mail: neuropub@dignityhealth.org]

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residents in other training programs. Standard guidelines on radiation limits for residents and the acceptable levels of exposure for a 7-year program are unknown. The first step in developing a culture of radiation safety is to establish a baseline rate of radiation exposure. Our institution, one of the largest neurosurgery residency training programs in the country, provides an ideal venue for determining radiation exposure among neurosurgery residents at a high-volume, multidisciplinary center in the modern era. Thus, we performed a retrospective review of a prospectively collected database for dosimeters placed outside the lead guard to determine the level of ambient radiation to unshielded body surfaces (eyes, arms, legs) of residents. In this study, we sought to determine the baseline level of radiation exposure among the trainees. Establishing a baseline level of radiation exposure may facilitate efforts to further decrease radiation exposure by neurosurgery residents. To our knowledge, the total radiation to which neurosurgery residents are exposed over a 7-year residency has not been reported previously.

METHODS

After approval by the Institutional Review Board at St. Joseph's Hospital and Medical Center, a retrospective analysis was performed of a prospectively collected radiation database of all neurosurgery residents at Barrow Neurological Institute from July 2009 to July 2014. During this period, radiolucent optically stimulated luminescence (OSL) detector chips (Landauer, Inc., Glenwood, Illinois) were used to analyze the surface radiation dose exposure by neurosurgery residents during intraoperative or angiographic suite procedures.[28] OSL detector chips composed of carbon-doped aluminum oxide crystals (Al_2O_3:C) are a commercially available method to detect radiation levels with comparable accuracy with conventional thermoluminescent detectors.[29] Landauer Inc. performed the calibration and readout of the OSL chips according to standard industry practices, with a measuring capability of 1 mrem.[28] OSL dosimeter chips were placed outside a personalized lead thyroid guard and replaced every 3 months by a trained radiation physicist. This location was chosen because it was deemed less cumbersome and less of a potential threat to sterility than placement of the dosimeters adjacent to the head or on a ring finger during surgical procedures. Residents were encouraged to use personalized lead thyroid shields and lead aprons that covered the torso and hips, as well as eye shields that were provided by Barrow Neurological Institute. However, residents did not undergo formal radiation safety courses before initiation of the prospective study. Instances in which residents elected not to wear lead protection and instead simply stood in the substerile room during localization radiographs were not tracked. Radiation exposure measurements were available for analysis only when residents chose to wear their personalized lead garment during fluoroscopy-guided procedures. Standard radiation protection precautions were used throughout the study period. Furthermore, given the retrospective nature of this review, specific resident cases were not collected for review. However, residents generally wore lead guards for instrumented spinal procedures, minimally invasive procedures, and endovascular procedures. Residents typically did not wear lead guards in cases where fluoroscopy was not used (cranial cases) and for noninstrumented spine cases (e.g., spinal cord tumor resection, spinal decompression).

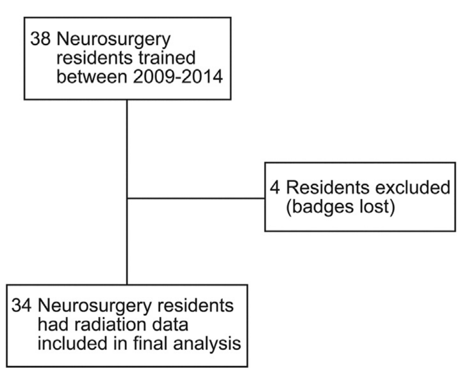

Figure 1. Flow diagram demonstrating which residents ultimately met the inclusion/exclusion criteria. (Used with permission from Barrow Neurological Institute, Phoenix, Arizona.)

RESULTS

We retrospectively reviewed a prospectively collected radiation dosimetry database for badges placed outside lead protection guards. From July 2009 to July 2014, a total of 38 neurosurgery residents were enrolled at Barrow Neurological Institute. Four residents had no radiation data available in the database due to lost badges, leaving 34 neurosurgery residents (30 male, 4 female) with badges available for final analysis (Figure 1). A total of 20,541 days of radiation monitoring data were available for analysis. The OSL radiation detection chips placed on the outside of the thyroid lead guard were analyzed by Landauer Inc. with the analyzed radiation exposure data represented as the deep dose equivalent (DDE). The DDE is the whole-body radiation exposure dose estimated from a single badge worn near the collar area outside a protective apron, or a collar, or a glove. For the study period, the average DDE was 0.67 ± 0.75 mrem per resident/day (range, 0.03–3.21 mrem per resident/day). Radiation exposure over time is illustrated in Figure 2. Our findings showed no correlation between the degree of radiation exposure and the duration of exposure (correlation coefficient, $r = 0.262$). This suggests that over the course of the 5 years that the residents were monitored, radiation exposure rates were essentially equivalent from year to year. The projected maximum exposure during the course of residency training was 12.15 ± 13.50 mSv. For context, Table 1 summarizes the typical effective dose of radiation from a single exposure to common diagnostic medical imaging modalities and the amount of ambient radiation to which a neurosurgery resident was typically exposed over 7 years. The latter was equivalent to approximately 6 computed tomography (CT) scans of the head.

DISCUSSION

Main Results

Radiation exposure during the course of neurosurgical residency training has not been well defined previously. Our findings

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