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Radiation brain dose to vascular surgeons during fluoroscopically guided interventions is not effectively reduced by wearing lead equivalent surgical caps

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ABSTRACT

Objective: Radiation to the interventionalist's brain during fluoroscopically guided interventions (FGIs) may increase the incidence of cerebral neoplasms. Lead equivalent surgical caps claim to reduce radiation brain doses by 50% to 95%. We sought to determine the efficacy of the RADPAD (Worldwide Innovations & Technologies, Lenexa, Kan) No Brainer surgical cap (0.06 mm lead equivalent at 90 kVp) in reducing radiation dose to the surgeon's and trainee's head during FGIs and to a phantom to determine relative brain dose reductions.

Methods: Optically stimulated, luminescent nanoDot detectors (Landauer, Glenwood, Ill) inside and outside of the cap at the left temporal position were used to measure cap attenuation during FGIs. To check relative brain doses, nanoDot detectors were placed in 15 positions within an anthropomorphic head phantom (ATOM model 701; CIRS, Norfolk, Va). The phantom was positioned to represent a primary operator performing femoral access. Fluorography was performed on a plastic scatter phantom at 80 kVp for an exposure of 5 Gy reference air kerma with or without the hat. For each brain location, the percentage dose reduction with the hat was calculated. Means and standard errors were calculated using a pooled linear mixed model with repeated measurements. Anatomically similar locations were combined into five groups: upper brain, upper skull, midbrain, eyes, and left temporal position.

Results: This was a prospective, single-center study that included 29 endovascular aortic aneurysm procedures. The average procedure reference air kerma was 2.6 Gy. The hat attenuation at the temporal position for the attending physician and fellow was 60% ± 20% and 33% ± 36%, respectively. The equivalent phantom measurements demonstrated an attenuation of 71% ± 2.0% ($P < .0001$). In the interior phantom locations, attenuation was statistically significant for the skull (6% ± 1.4%) and upper brain (7.2% ± 1.0%; $P < .0001$) but not for the middle brain (1.4% ± 1.0%; $P = .15$) or the eyes (−1.5% ± 1.4%; $P = .28$).

Conclusions: The No Brainer surgical cap attenuates direct X rays at the superficial temporal location; however, the majority of radiation to an interventionalist's brain originates from scatter radiation from angles not shadowed by the cap as demonstrated by the trivial percentage brain dose reductions measured in the phantom. Radiation protective caps have minimal clinical relevance. (J Vasc Surg 2018;■:1-5.)

Radiation exposure has become a major occupational health concern among vascular surgeons. Radiation exposure can result in stochastic or deterministic effects. Deterministic effects, most notably skin injury and cataract development, are caused by cell damage or death. The severity of the effect is dose related once a threshold radiation dose is reached.[1,2] A stochastic effect, or cancer development, is largely due to misrepair of damaged DNA resulting in genetic transformation. The likelihood of stochastic effects increases with the total radiation energy absorbed by the different organs, but their severity is independent of total dose. Stochastic effects generally are not manifested until years to decades after exposure.[2]

Vascular surgeons are exposed to significant scatter radiation during fluoroscopically guided interventions (FGIs).[3] Radiation-attenuating personal protection includes aprons to protect radiosensitive body organs and glasses to prevent cataract development. Typically, the head is not protected, in part because of the low radiosensitivity of the brain.[4,5] Although malignant brain tumor accounts for only 2% of cancers each year in the United States, radiation is a known risk factor for its development.[6] An interventional cardiologist's annual head exposure ranges from 20 to 30 mSv/y, which is

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nearly 10 times greater than the whole body's exposure.[7] Interestingly, the left side of the head has been shown to experience twice the exposure levels of the right side.[8]

Recent reports suggest an increased risk of malignant brain tumors in interventionalists, with a proclivity toward left-sided lesions.[6,9,10] With this concern, lead equivalent cranial caps have been developed and are being marketed as a device that significantly decreases exposure to the interventionalist's brain during FGIs. Recent studies, including the Brain Radiation Exposure and Attenuation During Invasive Cardiology Procedures (BRAIN) study, have reported that using a lead equivalent surgical cap can reduce scatter radiation dose to the brain of interventionalists to a nominal amount.[11] Additional studies have supported this claim that wearing a lead equivalent surgical cap can significantly reduce the operator's head radiation exposure.[12]

Our hypothesis is that the operator's radiation dose at the left temporal position during FGIs does not reflect brain dose. The aim of this study was to determine the efficacy of the RADPAD (Worldwide Innovations & Technologies, Lenexa, Kan) No Brainer surgical cap in reducing radiation dose to the surgeon's and trainee's head during FGIs and to a phantom to determine relative brain dose reductions.

ARTICLE HIGHLIGHTS

- **Type of Research:** Prospective cohort and experimental studies
- **Take Home Message:** Brain radiation dose was measured during 29 endovascular procedures and in head phantoms using lead equivalent RADPAD (Worldwide Innovations & Technologies, Lenexa, Kan) No Brainer surgical caps. The cap attenuated direct X rays at the superficial temporal location; however, the majority of radiation to the brain was not shadowed.
- **Recommendation:** This study suggests that caps currently do not provide satisfactory brain protection from radiation.

METHODS

Two experiments were performed in this study. The first was a single-center prospective study. The attenuation of the blue (0.06 mm lead equivalent at 90 kVp) surgical cap (RADPAD No Brainer) was verified by comparing it with lead foil (99% purity) using a 90-kVp primary narrow beam geometry from a diagnostic X-ray generator. Optically stimulated, luminescent nanoDot detectors (Landauer, Glenwood, Ill) inside and outside of the cap at the left temporal position were used to measure radiation attenuation for the attending surgeon and the trainee during FGIs. The nanoDots were read using a Landauer microSTARii medical dosimetry system. For each procedure, the attenuation was calculated, and a weighted average was obtained using weights equal to 1/variance. Institutional Review Board approval and consent of the patient were waived for this study because the study was deemed quality improvement, not meeting the definition of human subject research and intended only for the improvement of local processes.

The second experiment was performed to check relative brain doses with and without the cap in a controlled phantom study. The nanoDot detectors were placed in 15 positions within an anthropomorphic head phantom (ATOM model 701; CIRS, Norfolk, Va; Fig 1). Measurements were made with the phantom at the position for a primary operator performing right femoral access for an FGI. A lead apron was not worn by the phantom because it was not considered relevant to brain dose. A plastic phantom simulated the patient, and fluorography was performed at 80 kVp for an exposure of 5 Gy reference air kerma with and without the hat; the experiment was repeated three times (Fig 2). For each brain location, the attenuation (percentage dose reduction) with the hat was calculated. Means and standard errors were calculated using a pooled linear mixed model with repeated measurements. Anatomically similar locations were combined into five groups (Fig 1): upper skull (top slab of phantom head), upper brain (second slab of phantom head), midbrain (middle slab of phantom head), eyes (ocular position of phantom head), and left temporal position (on the surface of the phantom head). The mean attenuation of each location was tested against the null hypothesis of no hat effect (attenuation = 0). *P* values were calculated for testing the null hypothesis that the attenuation was 0. A *P* value $<.05$ was statistical evidence against the null hypothesis.

RESULTS

The measured lead equivalency of the hat was 0.05 ± 0.01 mm using a 90-kVp/3-mm aluminum half-value layer quality beam. This is consistent with the manufacturer's specification of 0.06 mm at 90 kVp. Twenty-nine endovascular aortic aneurysm procedures were studied. The average reference air kerma was 2.6 Gy. The hat attenuation at the external skull temporal position for the attending physician and fellow was 60% ± 20% and 33% ± 36%, respectively. The equivalent phantom measurements demonstrated an attenuation of 71% ± 2.0% ($P < .0001$). In the interior phantom locations, attenuation was statistically significant for the skull (6% ± 1.4%) and upper brain (7.2% ± 1.0%; $P < .0001$) but not for the middle brain (1.4% ± 1.0%; $P = .15$) or the eyes (−1.5% ± 1.4%; $P = .28$; Fig 3).

DISCUSSION

A recent publication reported 31 cases of interventionalists who developed brain cancer.[6] The majority of these cancers were glioblastoma multiforme (55%), with two