JACC: CARDIOVASCULAR INTERVENTIONS VOL. 10, NO. 5, 2017

ISSN 1936-8798/$36.00
PUBLISHED BY ELSEVIER http://dx.doi.org/10.1016/j.jcin.2016.11.026

RADIATION SAFETY

Head and Neck Radiation Dose and Radiation Safety for Interventional Physicians

Kenneth Fetterly, PhD,[a] Beth Schueler, PhD,[b] Michael Grams, PhD,[c] Glenn Sturchio, PhD,[d] Malcolm Bell, MD,[a] Rajiv Gulati, MD[a]

ABSTRACT

OBJECTIVES The first aim of this study was to assess the magnitude of radiation dose to tissues of the head and neck of physicians performing x-ray-guided interventional procedures. The second aim was to assess protection of tissues of the head offered by select wearable radiation safety devices.

BACKGROUND Radiation dose to tissues of the head and neck is of significant interest to practicing interventional physicians. However, methods to estimate radiation dose are not generally available, and furthermore, some of the available research relating to protection of these tissues is misleading.

METHODS Using a single representative geometry, scatter radiation dose to a humanoid phantom was measured using radiochromic film and normalized by the radiation dose to the left collar of the radioprotective thorax apron. Radiation protection offered by leaded glasses and by a radioabsorbent surgical cap was measured.

RESULTS In the test geometry, average radiation doses to the unprotected brain, carotid arteries, and ocular lenses were 8.4%, 17%, and 50% of the dose measured at the left collar, respectively. Two representative types of leaded glasses reduced dose to the ocular lens on the side of the physician from which the scatter originates by 27% to 62% but offered no protection to the contralateral eye. The radioabsorbent surgical cap reduced brain dose by only 3.3%.

CONCLUSIONS A method by which interventional physicians can estimate dose to head and neck tissues on the basis of their personal dosimeter readings is described. Radiation protection of the ocular lenses by leaded glasses may be incomplete, and protection of the brain by a radioabsorbent surgical cap was minimal.
(J Am Coll Cardiol Intv 2017;10:520–8) © 2017 by the American College of Cardiology Foundation.

The potential for adverse health effects from occupational radiation exposure is of concern for interventional cardiologists, radiologists, and surgeons who routinely use x-ray fluoroscopy and angiography to diagnose and treat cardiac and vascular disease (1-4). Interventional physicians have an appetite for information that can help them assess their own health risks associated with occupational radiation dose. One aim of this work is to provide physicians a simple means to estimate radiation dose to tissues of the head, particularly the brain, carotid arteries, and ocular lenses.

Methods to minimize radiation dose to tissues of the head are also desired by interventional physicians

From the [a]Department of Cardiovascular Diseases, Mayo Clinic, Rochester, Minnesota; [b]Department of Radiology, Mayo Clinic, Rochester, Minnesota; [c]Department of Radiation Oncology, Mayo Clinic, Rochester, Minnesota; and the [d]Department of Diagnostic Radiology, Mayo Clinic, Jacksonville, Florida. The authors have reported that they have no relationships relevant to the contents of this paper to disclose.

Manuscript received June 27, 2016; revised manuscript received October 4, 2016, accepted November 17, 2016.

to mitigate risk for radiation injury. Appropriate x-ray shielding remains one of the fundamental ways to protect physicians from x-ray scatter. The potential for a ceiling-mounted upper body shield to protect the head and neck of physicians is well known (5–8). Other novel shielding devices (9–11) have not been widely adopted. The potential for leaded glasses to protect the eyes and thereby reduce cataract risk has long been known (12). The remainder of the head and superior portion of the neck frequently do not have dedicated radiation protection. Radioprotective surgical caps have been proposed to reduce dose to the brain (13–15). The second aim of this work was to assess the potential for select wearable radiation protection devices to reduce dose to tissues of the head, particularly the brain and ocular lenses, and provide interventional physicians practical guidance in the effectiveness of these devices.

METHODS

Primary experimental methods used for this work were described elsewhere (Fetterly et al. [16]). Therefore, only a brief summary of those methods and relevant enhancements to support this work are included here. Preliminary experiments characterized the energy of scattered radiation emitting from a patient (phantom) during an x-ray angiographic procedure. Four different scatter beam qualities were selected to mimic scatter associated with patient sizes ranging from a small child to a large adult. A standard x-ray tube was tuned to mimic the 4 scatter beam qualities by adjusting the peak tube potential (56, 74, 90, and 106 kVp) and half-value layer (3.5, 4.5, 5.5, and 6.5 mm Al) of the beam. The scatter-equivalent beams were directed upon an anthropomorphic phantom (Alderson, RANDO phantom, Radiology Support Devices, Long Beach, California) to estimate scatter radiation dose to the head and neck of an interventional physician (**Figure 1**). The transverse plane slabs of the phantom were assembled on a table to simulate an upright physician. Radiochromic film (XR-QA2, Ashland, Bridgewater, New Jersey) was placed within transverse planes of the phantom to measure tissue dose. The scatter-equivalent radiographic x-ray beam and phantom were positioned and oriented to mimic scatter incident upon a physician performing a left femoral access cardiac interventional procedure. The phantom was covered with a 0.5-mm lead-equivalent radioprotective apron, and 3×3 cm^2 pieces of radiochromic film were attached to the outside of the lead apron at locations to mimic a personal dosimeter located at the left and right collars (**Figure 1**). Our previous work reported the influence of scatter beam quality or energy on the percentage of left collar dose (LCD) (16). This work reports a composite or typical dose that is the average percentage LCD associated with the various scatter beam qualities.

A single scatter-equivalent x-ray beam (90 kVp; half-value layer 5.5 mm Al) was used to assess select radiation safety devices, including 2 types of radioprotective glasses (**Figure 2**) (glasses 1: 0.75-mm lead equivalent, Liberty MX30, Phillips Safety Products, Middlesex, New Jersey; glasses 2: 0.07-mm lead equivalent, XR-700, Toray Medical, Toray International America, Houston, Texas), a commercially available radiopaque surgical cap (No-Brainer 9100, RadPad Protection, Kansas City, Kansas), and a radiopaque hood fabricated in our laboratory from the material of the radiopaque surgical cap (**Figure 3**). The surgical cap was positioned on the phantom such that the inferior portion of the cap was in contact with the auricles of the ears and just superior to the location corresponding to the superciliary arches and eyebrows. Similar to that described by Kuon et al. (7), the hood was fashioned to hang along the side of the face of the phantom, around to the back of the neck, and extend from the surgical cap inferiorly to the level of the phantom chin (**Figure 3**). Anatomic regions protected by the wearable shielding devices were represented by a region of x-ray shadow recorded in the radiochromic film. The reduction in radiation dose to tissues protected by the devices was estimated by comparing radiochromic film dose measurements with and without the protective devices.

After exposure, the radiochromic films were scanned with a flatbed scanner, resulting in 2-dimensional (2D) transverse plane dose distribution maps. The 2D dose maps were normalized by the dose received by the LCD, resulting in 2D maps of dose as a percentage of the LCD. Computed tomographic images of the phantom were overlain onto the 2D dose maps to provide bony landmarks. Dose to select organs and tissues, including the left and right brain, whole brain, brain stem, ocular lenses, and carotid arteries, was calculated.

RESULTS

Percentage of LCD maps corresponding to the 90-kVp scatter-equivalent beam are shown in **Figure 4**. The color scale of **Figure 4** ranges from 0% LCD (dark blue) through 100% LCD (yellow). The percentage LCD decreased rapidly from the anterior left (x-ray beam entrance) surface of the phantom and was consistent with expectations of exponential attenuation of the

ABBREVIATIONS AND ACRONYMS

2D = 2-dimensional

ERR = excess relative risk

LCD = left collar dose