TECHNICAL NOTE

Radiation Exposure to the Primary Operator During Endovascular Surgical Neuroradiology Procedures

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SUMMARY: Endovascular surgical neuroradiologists can receive a substantial amount of occupational radiation exposure. We evaluated the amount of radiation exposure that results from the practice of performing hand injections during digital subtraction angiography (DSA). The primary operator can significantly decrease the radiation dose by leaving the room for DSA procedures. However, the total radiation dose for the primary operator is relatively low and is certainly within allowable regulatory limits when extrapolated to a yearly dose.

Out of sight, out of mind can be applied to the scattered radiation present during angiography. Angiographers can receive significant occupational exposures if safeguards are not instituted to limit their risk. Endovascular surgical neuroradiology sessions are often long and can span several hours in difficult cases. The concept of limiting radiation exposure to as low as reasonably achievable mandates that physicians who use ionizing radiation in their practice limit unnecessary exposure to patients, ancillary staff, and themselves.[1] Several variables with a wide variation in use have a direct influence on operator radiation exposure. One such variable is the performance of hand injections during digital subtraction angiography (DSA) in lieu of using a power injector. Hand injection technique requires that the primary operator stay near the patient to inject the contrast, whereas the power injector procedures allow the operator to step away from the table, therefore reducing his or her exposure to scattered radiation. We attempted to measure the additional radiation exposure to a primary operator during endovascular head and neck sessions that results from standing at the table during DSA acquisitions.

Description of Technique

Two collar dosimeter badges (Luxel+, Landauer, Inc, Glenwood, Ill) were worn on the top of a thyroid shield for a month by a single primary operator. A third control badge was placed in the back of the room approximately 5 m from the x-ray tube. During the sessions, 1 collar badge was worn continuously (badge 1) and the second collar badge was removed by an assistant for the DSA procedures (badge 2) and placed on a table beside the control badge (badge 3). By this means, the total radiation dose for the sessions could be measured as well as the dose attributed to the DSA portion of the examinations. Except for 3D rotational angiography, all DSA injections were performed by hand. Even during 3D rotational procedures using the power injector, the primary operator stood in the same position at the table. All imaging was performed on a biplane angiography unit (Integris Allura, Philips Medical Systems, Best, the Netherlands) with integrated dose area product (DAP) ionization chambers. The system was configured to use an additional 0.1 mm of copper (Cu) filtration during fluoroscopy only. A Mavig-Portegra 2 (Mavig, Munich, Germany) ceiling-mounted lead acrylic window shield was used in all sessions and positioned to block scatter radiation from the exposed patient tissue.

The primary operator was an interventional neuroradiology fellow who stood in the typical position on the patient's right side. A common femoral artery approach was used for arterial access, and in cases requiring venous access, the common femoral vein was used. The distance between the primary operator's collar badge and the exposed patient volume was approximately 1.5 m. Readings from the dosimeter badges were obtained for deep-dose equivalent (DDE), which applies to external whole-body exposure, and lens-dose equivalent (LDE), which applies to orbital lens exposure. The DAP for patient exposure from fluoroscopy and DSA was recorded from the angiography console in each case as well as the total fluoroscopy time per case.

During 1 month, 29 procedures were performed. The procedures were composed of a mixture of diagnostic and interventional cases of the head and neck, which are listed in Table 1, along with the average fluoroscopy time. The total radiation dose (badge 1), the fluoroscopy dose (badge 2), the DSA dose (badge 1 minus badge 2), and the percentage of the total dose attributed to DSA are given in Table 2. The control badge (badge 3) had a negligible dose ($<$0.01 mSv). The average patient DAP, obtained from the angiography unit was 68 Gy cm^2 (range, 17–173 Gy cm^2), and the percentage of the total patient DAP resulting from DSA was 78% (range, 48%–96%).

Discussion

Operator exposure during angiography has been reported in the interventional cardiology and neuroradiology literature.[2-8] Previous reports have documented the utility of protective devices such as pull-in lead shields and lead aprons as well as increasing operator distance from the primary beam for reducing radiation dose to angiographers.[3,9] In fact, these practices are now commonplace for all angiographic procedures when patient and instrument positioning allows. Practice patterns vary widely concerning the use of hand injections versus automated power injections for DSA. With the advent of minimally invasive endovascular surgical techniques, the practice of performing hand injections for DSA procedures has become more common. Because endovascular interventions are often long procedures, time-saving techniques such

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Table 1: Case mixture and average fluoroscopy time

	No. of Cases	Average Fluoroscopy Time per Case (min)
Diagnostic angiograms	14	7
Aneurysm coilings	6 (in 5 patients)	29
ECA embolizations	5	22
dAVF embolizations	2	42
Carotid stents	1	20
Test balloon occlusions	2	19

Note:—ECA indicates external carotid artery; dAVF, dural arteriovenous fistula.

Table 2: Dosimeter readings and radiation exposure

	DDE (mSv)	LDE (mSv)
Badge 1 (total dose)	0.94	1.11
Badge 2 (fluoroscopy dose)	0.13	0.23
DSA dose	0.81	0.88
% total dose from DSA	86	79

Note:—DDE indicates deep-dose equivalent; LDE, lens-dose equivalent; DSA, digital subtraction angiography.

as hand injections have evolved as a consequence. Furthermore, some operators prefer hand injections to power injector procedures because of the immediate feedback and ability to stop the injection in cases of catheter or patient movement.[3] The use of microcatheters also generally requires manual injections because volumes of <1 mL are often used in small-caliber vessels. Power injection through a microcatheter in a small distal branch is contraindicated because of the potential for vessel or microcatheter rupture.

DSA has been shown to be the primary contributor to operator radiation exposure during diagnostic and interventional radiology procedures. Previous reports have documented the percentage of total dose due to DSA as 75%–92% during interventional cardiology and radiology sessions.[3,4,7,8] In fact, a single DSA procedure in some cases may expose the operator to more radiation than the fluoroscopy dose from the entire procedure.[2] Our results for endovascular neuroradiology sessions are compatible with these previous reports and document that DSA provides 79%–86% of the primary operator's total radiation dose. Although we did not specifically measure the radiation dose to the primary operator's hands, previous studies have documented increased exposure to the left hand during manual DSA injections.[2] Note that for our study, Cu filtration was used for the fluoroscopic portion of the procedure only. Use of Cu filtration for DSA would result in an additional dose reduction for the patient and operator during this portion of the procedure. However, we do not routinely use Cu filtration for DSA because of issues with tube overheating on the Philips unit. A small fraction of the DSA procedures and, therefore, the DSA dose in our study was necessarily performed by hand for microcatheter procedures. However most DSA procedures used a diagnostic or guiding catheter and could have been performed with a power injector. If the operator also stood back 5 m from the table (same distance as badge 3), essentially all of the dose from DSA could be eliminated.

Even though DSA contributes most to operator exposure during the session, the total radiation dose is still relatively low. In our practice, even with the use of hand injections, the total radiation dose is still within allowable yearly limits (50-mSv effective dose equivalent, 150-mSv LDE) when extrapolated over a 12-month period.[1] The projected yearly dose for the caseload experienced during this study is 11.3-mSv DDE and 13-mSv LDE. Assuming that a lead protective apron is worn, we estimate the effective dose equivalent as 2 mSv for 1 year on the basis of the guidelines set forth by the National Council on Radiation Protection and Measurements.[10] Different practices might expect different results depending on their caseload, experience, fluoroscopy habits, and angiography unit dose settings. However, the fraction of the total dose from DSA would be expected to increase for more experienced operators as the amount of fluoroscopy during the procedure decreases. Furthermore, the case mixture in a given practice will also influence an operator's total dose and the fraction attributable to DSA.

Several investigators have shown that operator exposure levels are proportional to the patient DAP, which is calculated by the angiography unit on the basis of collimator settings and exposure factors.[11-14] In our study, the fraction of patient DAP from DSA averaged 78%, which was very close to our badge measurements for the operator's DSA dose. Because the DAP measurement is performed automatically on most modern angiography units, it is possible for any given operator performing hand injections to estimate the dose reduction that would occur if power injection was used instead.

Conclusion

Endovascular surgical neuroradiologists who routinely perform hand injections during head and neck procedures receive $>75\%$ of their dose from DSA. Patient DAP measurements can be used to estimate a given operator's expected DSA dose contribution to his or her total dose. Whether the dose exposure saved by standing away from the table justifies the increased procedure time is a philosophic question that individual radiologists must answer for themselves.

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