What is the Life Expectancy for Your Lead Apron?
Are Your Lab Teams Protected?

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Every year and especially at the beginning of the academic year, we have requests from new cath lab staff and some faculty or fellows about getting a new lead apron for procedures using fluoroscopy. As an owner of an old lead apron, I was asked, "How long do our old lead aprons last?" The answer, of course, is "that depends." How many times is it used every day? Is it folded, dropped, put on a hanger? There are other factors, but from a quick review (on the internet) it seems that lead aprons should last about 10 years. Defects (cracks, tears) are assumed to appear, on average, at about 5 years. In some labs, the fabrics or stitching has torn or frayed, and requires replacement. My current lead apron is one such example (Figure 1). In 2015, we talked about checking the lead aprons and other radiation protection methods.[1] I thought it would be a good time to review the subject and update our cath lab practices.

Figure 1. **Lead apron showing tears in fabric at neck from frequent use, despite correct hanging on the lab's lead rack.**

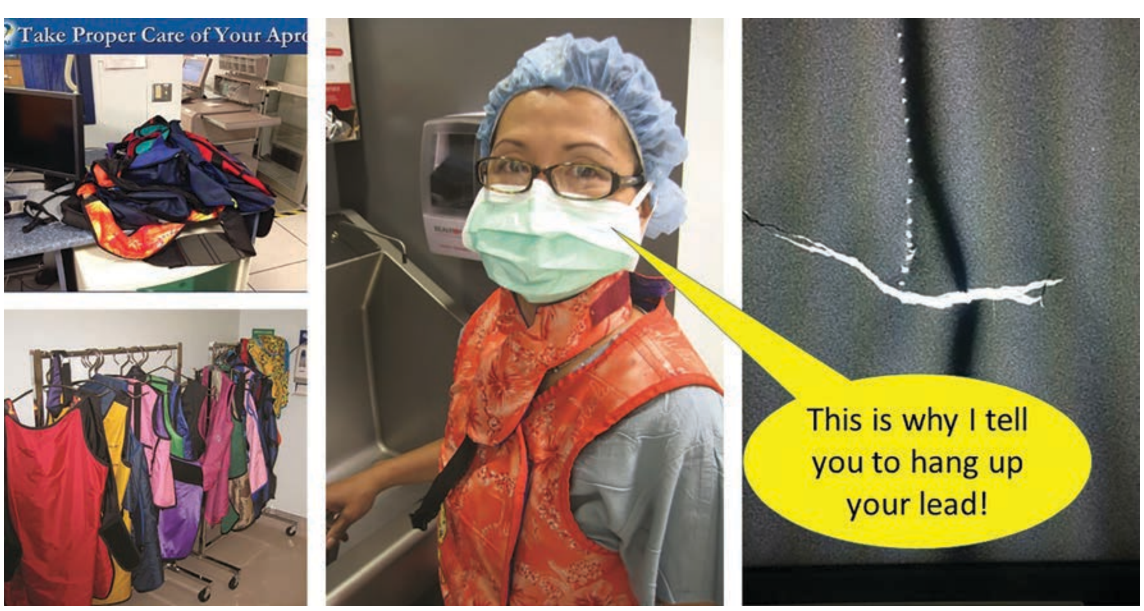

Figure 2. **Top left, lead aprons piled up. Bottom left, correct method of hanging lead aprons. Far right panel shows an x-ray image of cracked lead. Our tech reminds us of why we hang lead.**

Variables Impacting Lead Protective Qualities

A number of factors impact the life of an x-ray apron. These include the frequency of daily use, the manner in which it is stored (hung up) and the handling of the lead during donning and doffing. X-ray aprons should never be folded. Cracks in the lead lining can develop at the fold, reducing the useful life of the apron (Figure 2). Properly caring for your lead apron is essential to getting the most useful life from your apron.

Lead Apron Integrity Inspection

It is recommended to have the lead apron examined fluoroscopically at least once a year. The x-ray apron should be inspected annually or per manufacturer recommendations. The process is straightforward and often done in conjunction with the hospital's radiation safety officer. The fluoroscopic inspection starts with placing the apron on the x-ray table. Then scan and examine the entire x-ray apron using the fluoroscope. The results of the inspection should follow your facility's or state's radiation safety protocols.

Lead aprons are required protection for anyone working in or around areas with ionizing radiation (cath and electrophysiology labs, fluoroscopic areas in the operating room, pulmonary or intensive care unit, or emergency department). Any individual risking exposure to radiation must wear protective garments. Lead aprons or skirt/vest combination garments should have sufficient shielding. Lead aprons absorb 90-95% of scattered radiation that reaches them. Lead aprons generally have shielding equivalence equal to an 0.25-0.5 mm lead and thus do not completely block, but only attenuate, the radiation. A lead apron with an 0.35 mm lead thickness equivalence should be sufficient for most fluoroscopic procedures. For high workloads, a wrap-around lead apron with an 0.25 mm lead equivalence that overlaps on the front, and provides

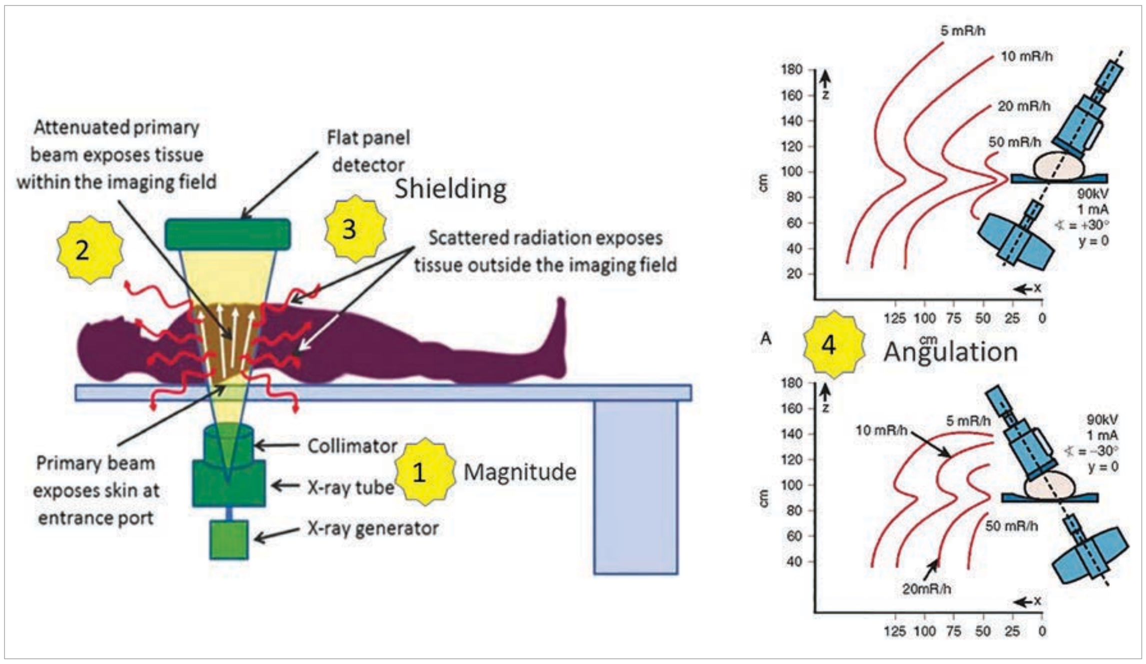

Figure 3. **Determinants of Radiation Exposure. Diagrammatic Representation of an X-Ray Fluoroscopy System to Illustrate X-Ray Exposure Modality. The primary beam, collimated to a rectangular cross section, enters the patient, typically through the patient's back. It is attenuated and scattered within the imaging field. The primary beam exposes the subject within the imaging field. The scattered primary beam radiation can expose structures within the subject that are remote from the imaging field. The 4 methods of reducing exposure include (1) magnitude of exposure, (2) reducing of scatter, (3) application of shielding, and (4) minimizing angulation when possible.**
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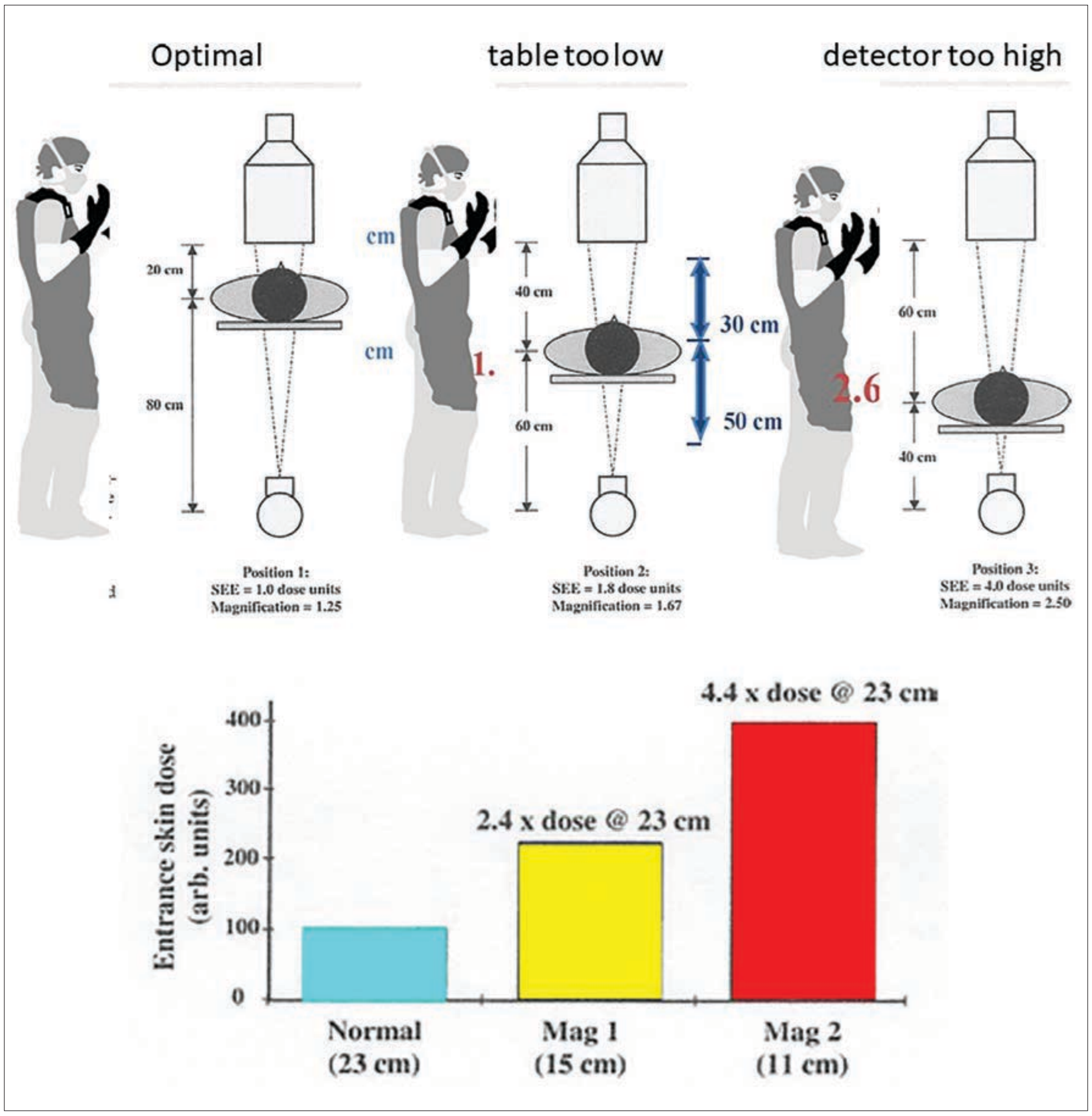

0.25+0.25=0.5 mm lead equivalence on the front and 0.25 mm on the back would be ideal. For a low workload, an 0.25 mm lead equivalence apron should do well.

Lead aprons protect sensitive body organs and also reduce the total body effective exposure dose by up to 85%. Wrap-around lead aprons are useful when medical personnel face away from the tube and away from the patient. Logically, then, when using aprons which are not 360-degree coverage, operators and staff should not turn away from the tube during beam activation.

In additional to the body lead apron (shoulder to mid-calf), a neck or thyroid lead collar is standard. The thyroid is very radiosensitive and hence, the lead collar protects the thyroid from the minimal exposure, reducing the total effective dose by a factor between 1.7 and 3. For eye protection to reduce the change of cataracts, some personnel wear protective 0.15 mm lead-equivalent glasses or goggles that limit the eye lens dose and provide about 70% attenuation even in high energy (kVp) beams. Protective eyeglasses reduce eye exposure during fluoroscopy. Leaded eyewear is recommended for personnel with high exposure, such as those who accumulate monthly radiation badge readings >400 mrem (4 Sv). Levels of exposure in this range are typically encountered only in areas where continuous cineangiography is performed (e.g., the cardiac catheterization laboratory).

Radiation scatter and exposure at a distance depends on the angle of the gantry and distance of the x-ray tube to the patient (Figure 3). The tube position relative to the patient and the table height (Figure 4) will determine the amount of radiation scatter.

Figure 4. **Tube positioning affects radiation dose to both patient and operator. Diagrammatic Representation of the Effect of System Positioning on Patient and Operator Radiation Exposure During X-Ray Fluoroscopy. Note that in the "table too low" circumstance, the entrance port dose delivered to the patient is increased compared with optimal positioning. In the "table too low, detector too high" circumstance, the entrance port dose to the patient is further increased. In addition, in the "table too low" circumstance, the scattered dose to the operator increases, because less of the scattered dose is intercepted by the detector.**
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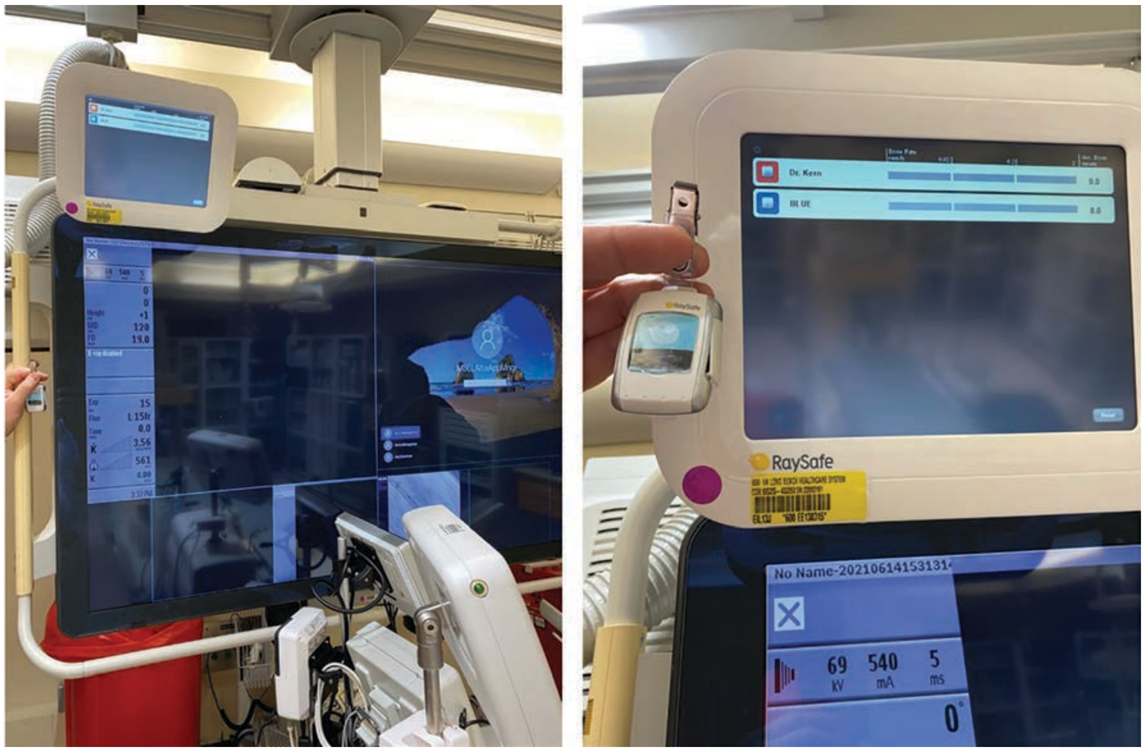

Figure 5. RaySafe radiation real-time radiation monitor (Fluke Biomedical). Each member of the team wears a badge that transmits the dosage to the display for all to see and take appropriate steps to reduce exposure.

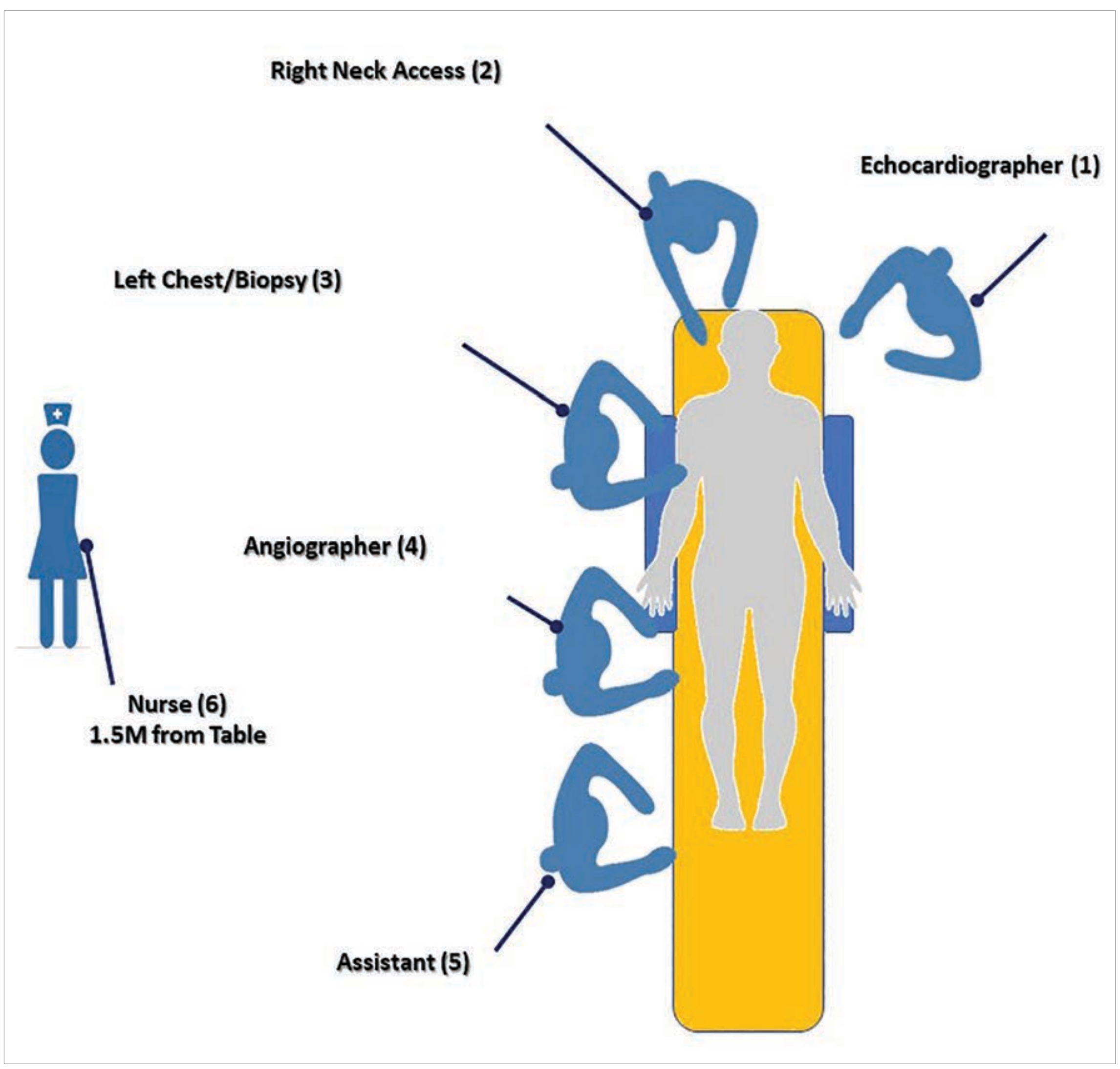

Figure 6. Diagram of locations which are exposed to radiation in the cath lab. Compared to the pre-structural heart disease era, there are now personnel located closer to the x-ray tube for anesthesia and transesophageal echocardiogram (TEE) operations. The personnel with the highest exposure are those closest to the patient's head and those on the tube side of the table when the gantry is angulated. *Courtesy of Dr. Robert Wilson.*

Table 1. Routine methods to limit exposure.

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Radiation to Patient	
1.	Originates from the primary x-ray beam and then scatters on, passing through the body.
2.	Affects thyroid, eyes, gonads, bone marrow, or gastrointestinal tract.
3.	Highest exposure of any diagnostic test.
Radiation to Staff	
1.	Long-term low dose from scatter and tube leakage.
2.	Affects thyroid and eyes.
3.	Accepted occupational exposure.
Means of Limiting Dose	
1.	Maintain equipment safeguards.
2.	Optimize milliamperage and kilovoltage.
3.	Minimize exposure time. Limit the fluoroscopic or cineangiographic time (cineangiographic time produces much greater exposure than fluoroscopic time).
4.	Minimize scatter with shielding and techniques. Use collimators. Reduce the distance between the x-ray source and the patient.
5.	For staff, maximize distance from source. Maximize the distance between the x-ray source and the operator and assistants.
6.	Imaging techniques: Use slower panning and provide good initial angiographic setup. Angled views almost double the radiation. Keep the image magnification as low as possible.
7.	Use all protective measures. Wear leaded aprons (preferably wrap-around): 0.5 mm or more thickness provides 80% protection. Use extra shielding (leaded thyroid guards, lead glasses, and protective table shields).

The operator should be aware of these controllable variables, and take an active role in protecting the staff by holding back on fluoro when someone steps close to give medications or forgets to move the portable shield into position.

Where Should I Stand During a Fluoroscopic Procedure?

Radiation scatter and exposure at a distance depends on the angle of the gantry and distance of the x-ray tube to the patient (Figure 3). The tube position relative to the patient and the table height (Figure 4) will determine the amount of radiation scatter. Oblique views increase exposure dose, with the high dose coming from lateral views. Higher image intensifier distance from the patient also increases radiation scatter.

The operator should be aware of these controllable variables, and take an active role in protecting the staff by holding back on fluoro when someone steps close to give medications or forgets to move the portable shield into position. Real-time fluoro dose monitor badges are useful in order to display the exposure each individual receives during the case on a screen near the monitors (Figure 5) (see the study by Murat et al in this month's issue for more information on real-time dosimetry).

Measurements have shown that scattered radiation from a patient's body is more intense at the entrance side of x-ray beam, i.e., on the side where the x-ray tube is located. Therefore, it is better to stand on the side of the detector — that is, the exit side — and not on the x-ray tube side during a fluoroscopic procedure (Figure 6). Typically, only around 1% to 5% of the radiation to the patient's body comes out on the exit side. Standing on the side of transmitted beam, scattered radiation corresponds to only 1% to 5% of the incident beam intensity. One the opposite side, radiation corresponding to 100% of the entrance beam intensity may occur.

The Bottom Line

The life of lead aprons discussion leads our thinking on ways to keep up best practices for safety and the best place to work. Table 1 summarizes routine methods to limit radiation exposure. As a group working in a radiation environment, it is everyone's obligation to remain aware of reducing both personal and lab exposure. ■

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Disclosures: Dr. Morton Kern reports he is a consultant for Abiomed, Abbott Vascular, Philips Volcano, ACIST Medical, and Opsens Inc.

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Suggested Reading

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International Atomic Energy Agency (IAEA). Radiation protection of medical staff in interventional procedures. Accessed June 24, 2021. Available online at https://www.iaea.org/resources/rpop/health-professionals/interventional-procedures/radiation-protection-of-medical-staff-in-interventional-fluoroscopy

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