Your Lead is Cracked? Radiation Safety Revisited

Morton J. Kern, MD, with contributions from Steve Bailey, MD, University of Texas Health Science Center at San Antonio, Texas; Steve Balter, PhD, Columbia University, New York, New York; Charles Chambers, MD, Hershey, Pennsylvania; Prashant Kaul, MD, University of North Carolina, Chapel Hill, North Carolina; Ajay Kirtane, MD, SM, Columbia University, New York, New York; Mike Ragosta, MD, University of Virginia, Charlottesville, Virginia; Gurpreet Sandhu, MD, PhD, Mayo Clinic, Rochester, Minnesota.

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Disclosure: Dr. Kern reports he is a consultant and speaker for St. Jude Medical and Volcano Therapeutics, and a consultant for Opsens, ACIST Medical, Heartflow, and Merit Medical.

Recently, a cath lab director told me that the lab's radiation badge readings were returned sporadically over the last year. Although the readings they had were within normal limits, not all months were reported. His radiation safety officer was missing in action for the last year. Once concern was raised about badges, the lab's lead aprons were then examined (after a few years of no inspections). After the conversation and a similar concern, we checked the integrity of our lead aprons (Figure 1). With this in mind, I asked my cath lab expert colleagues a couple of short questions about radiation safety in their labs:

1. What is your routine for monitoring personnel in the lab? Who is charged with this duty? How is it reported?
2. How often are your lead aprons checked? By whom?
3. Who does the radiation safety officer report to?

As with our "Conversations in Cardiology", I thank my expert colleagues for their thoughtful contributions and insightful comments. Here's what they said.

Charles Chambers, Hershey, Pennsylvania: These are important questions that are seldom emphasized. Radiation safety should be an active component of all quality improvement activities for cath lab programs. This is not just as it applies to procedural radiation dose and potential high dose cases, but for the safety of all personnel who work in the lab. As covered in the Society for Cardiovascular Angiography & Interventions (SCAI) 2011 article in *CCI* on establishing a radiation safety program in the cardiac catheterization laboratory, equipment issues, training, personal dosimetry, and radiation dose management are all important issues to address on a routine basis.[1]

The following is the approach we use at Penn State Hershey:

We have monthly monitoring for our personnel and our dosimetry service. This is taken care of by Health Physics, which is part of the Department of Radiology. This information is provided to personnel via an ALARA (As Low As Reasonably Achievable) level 1 report if they exceed 10% (>40 mRem) of the allowed monthly maximum and via an ALARA level 2 report if they exceed 30% (>120 mRem) of the allowed monthly maximum. We use a calculation for the body dose that takes into effect the lead that personnel wear. Most use one dosimeter

continued on page 6

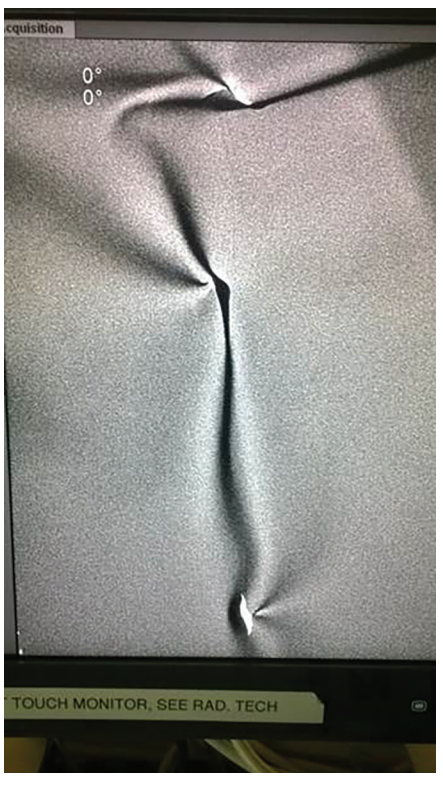

Figure 1. Three radiographs of lead aprons.

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Your Lead is Cracked?

Continued from page 4

at collar level (pregnancy obviously excluded). Ten years ago, cardiology had a 63% compliance with dosimetry use; by the director taking "an interest", this increased to near 100%.

Lead aprons are checked annually. Health physics is responsible for checking the aprons, but cath lab personnel actually do the physical checking, and give us the inventory sheet and attach the yearly color indicator for the year. Proper care of lead aprons is emphasized as part of the annual update on radiation safety (Figure 2), about what and what not to do with the lead aprons. I give the annual update talk in conjunction with our head of health physics. Trainees should leave their programs with verification of radiation safety training, as this may be required depending on the state they ultimately practice in.

For routine matters, the radiation safety officer reports to the chair of radiology. For radiation safety, he reports to the radiation safety committee and to the dean. This is an interesting issue since it is already very important to cardiology. Should cardiology have a physicist in the department, as the Mayo Clinic, Columbia University, and a few others, or should cardiology actively "own a piece" of the physicist so they have an obligation (skin in the game)? Just something to think about.

Steve Balter and Ajay Kirtane, Columbia University, New York, New York: Regarding badges, all cath lab workers are issued two badges (collar and body) on a monthly basis. Radiation safety is responsible for collection and monitoring. Reports are available online (instructions posted in the lab) or from the chief technologist. Radiation safety ALARA reports are generated when radiation levels exceed predetermined triggers (these are currently under revision for Columbia University Medical Center).

Lead aprons are checked twice a year by the technologists (using fluoro when necessary). All personal protective equipment (PPE) is tagged to identify and log the checks. Lead thickness is a matter of titrating radiation against orthopedic risks. My carrot to increase badge usage is that if an individual's values are low enough, thinner lead can be safely worn. The 0.5 mm regulation comes from the 1960 regulations that were aimed at gastrointestinal fluoro. In my humble opinion (IMHO) (and backed by data), 0.35 will reduce most operators' inside readings to minimal.

The radiation safety office reports to the Columbia Vice President for Environmental Health and Safety. There are specific instructions for doing the checks and for rejection criteria in the literature. Start with a relevant International Atomic Energy Agency (IAEA) website: www.rpop.iaea.org/.

Mike Ragosta, University of Virginia, Charlottesville, Virgina: At the University of Virginia Health System, we have a very robust radiation safety program:

1. One of the cath lab techs is tasked with routine monitoring and collects our dosimeter badges each month. The cath lab manager receives a report of dosimetry readings each month and reviews the data with staff.
2. Lead aprons are checked once a year by the cath lab chief imaging tech, and the data is collected and tracked. All lead in the hospital is tracked with a bar code system so that the radiation safety office knows where each piece is located and its status. The inspection includes a visual inspection and, if any concerns, the chief radiation safety officer is notified and the lead is assessed in a computed tomography (CT) scanner. If it doesn't pass, it is discarded.
3. The radiation safety officer reports to leadership in Environmental Health and Safety.

Table 1. Definitions of radiation units.

1	Roentgen (R) is the measure of ionization delivered to a specific point (exposure). One chest radiograph equals 3 to 5 mR.
2	Radiation absorbed dose (rad) is the amount of radiation energy deposited per unit mass of tissue. The amount of absorbed dose per given exposure depends on tissue type. For soft tissue, 1 R = 1 rad; for bone, 1 R = 4 rad (ie, greater absorption).
3	Radiation equivalent dose in man (rem) is used to express the biologic impact of a given exposure. For x-radiation, 1 rad = 1 rem.

Gurpreet Sandhu, Mayo Clinic, Rochester, Minnesota: The cath lab has a dedicated PhD-level medical physicist, engineering team, and tech supervisor supporting radiation safety measures locally. The aprons are screened annually, with additional checks if interim compromise is suspected. Radiation monitoring badge changes are done by a designated person, with documentation/individual reports/oversight provided by the institutional radiation safety office. The radiation safety office provides support at a variety of levels to ensure compliance with all regulations (Minnesota Department of Health, Nuclear Regulatory Commission, etc.), industry standards/guidelines, and best practices (Health Physics Society, National Council on Radiation Protection and Measurements, ANSI, etc.), accreditation standards, and Mayo policies.

Steve Bailey, University of Texas Health Science Center at San Antonio, San Antonio, Texas: We have dedicated training annually for all personnel who work in the lab. A senior RCVS is assigned monthly harvesting of badges and reporting. The results are posted and available to all. Our campus-wide radiation safety office performs annual validation of lead and it is replaced if defective.

Prashant Kaul, MD, University of North Carolina (UNC), Chapel Hill, North Carolina:

1. At UNC Chapel Hill, we have a designated person in the cath lab who is responsible for registering all employees with the department of radiation safety for the monitoring program. Dose reports are sent to our department on a monthly basis for posting and staff review.
2. Lead aprons are required to be checked at least once per calendar year. We have a designated cath lab technologist (who is ARRT [American Registry of Radiologic Technologist]-credentialed) who performs testing, on all new lead as well as all existing lead, annually. Documentation of this is maintained and is required for Joint Commission review.
3. Our radiation safety officer reports to our hospital radiation safety subcommittee.

The bottom line (and then some)

It is easy to become lackadaisical about proper personal radiation protection. We always believe our leads are in working order and often forget about methods to make sure they are. Let's keep in mind four basic principles about radiation exposure:

1. The less exposure, the better. Less exposure reduces chances of absorbed adverse biologic interaction.
2. There is no known permissible dose or absolutely safe level of radiation.
3. Radiation exposure is cumulative. There is no washout phenomenon.
4. Radiation safety is a team sport. All participants in the cardiac catheterization laboratory must actively work to reduce risks to other personnel and themselves.

Every cardiac catheterization laboratory should have a department-specific radiation safety policy which should include routine monitoring of personnel radiation exposure, continuing education programs for personnel on radiation safety, and the risks associated with radiation exposure, the requirement for all personnel to wear and maintain personal radiation protective equipment, procedures to check safety of all equipment (x-ray dose output, integrity of lead aprons, thyroid shields).

Complacency is human nature about our badges. Careful handling of radiation badges is an important part of the safety program. We usually don't pay very

Figure 2. (A) Folded leads (wrong way); (B) hanging lead aprons (right way).

continued on page 8

Your Lead is Cracked?

Continued from page 6

close attention to our badges, but this can cause considerable concern about quality in the lab should a badge be lost or fall under the x-ray unit, and inadvertently indicate someone received an excess exposure. To ensure accuracy, a badge should be attached to the person to whom it is assigned. Badges should never be left lying on a counter or on a lead apron in an area where there is radiation exposure. When badges are not being used, they should be stored away from any potential radiation exposure.

At the end of each month, the lab's designated radiation safety person collects the exposed badges. A monthly exposure report is posted for each staff member's exposure for that month. This information is anonymous to the staff but known to the cath lab supervisors and should be reviewed each month.

Radiation dose limitation

Although no known threshold for radiation exposure exists to define specific risks, the National Council on Radiation Protection and Measurements indicates that no dose of greater than 3 rem should be allowed over a 3-month period (see nomenclature for radiation doses, Table 1). There are several routine methods to limit exposure (from *The Cardiac Catheterization Handbook, 6th edition*, 2015[2]):

1. Wear leaded aprons (preferably wraparound): 0.5 mm or more thickness provides 80% protection.
2. Limit the fluoroscopic or cineangiographic time (cineangiographic time produces much greater exposure than fluoroscopic time).
3. Use collimators.
4. Reduce the distance between the x-ray source and the patient.
5. Maximize the distance between the x-ray source and the operator and assistants.
6. Limit the milliamperes per kilovolts as much as possible for an adequate image.
7. Use slower panning, and provide good initial angiographic setup. Angled views almost double the radiation.
8. Keep the image magnification as low as possible.
9. Use extra shielding (leaded thyroid guards, lead glasses, and protective table shields).

To assess the integrity of the lead, aprons should be examined under fluoroscopy at least once a year. Documentation should be kept regarding the integrity of each apron, each with some sort of identification (e.g., number, color, and name).

Lead aprons and thyroid shields

Lead aprons should contain 0.5-mm-thick lead lining. When properly cared for, an apron can provide years of service. The lead lining can crack or tear; however, this is usually caused by careless handling or improper storage. Aprons should be placed on an appropriate hanger or in a storage rack after use (Figure 2B). Repeatedly throwing an apron over a chair or stretcher may damage the lead lining.

To assess the integrity of the lead, aprons should be examined under fluoroscopy at least once a year. Documentation should be kept regarding the integrity of each apron, each with some sort of identification (e.g., number, color, and name). A hanging rack for the lead aprons will prevent cracking resulting from excessive folding of aprons left lying over chairs or benches.

I hope this brief review and questions prompts your lab to update its quality improvement initiatives about radiation safety. ■

References and suggested reading

1. Chambers CE, Fetterly K, Holzer R, Lin PJP, Blankenship JC, Balter S, Laskey WK. Radiation safety program for the cardiac catheterization laboratory. *Catheter Cardiovasc Interv.* 2011 Mar 1; 77(4): 546-556. doi: 10.1002/ccd.22867.
2. Kern M, Sorajja P, Lim MJ. *The Cardiac Catheterization Handbook*. 6th ed. Philadelphia, PA: Elsevier; 2016.
3. Michel R, Zorn MJ. Implementation of an X-ray radiation protective equipment inspection program. *Health Phys*. 2002 Feb; 82(2 Suppl): S51-S53.

LETTER TO THE CLINICAL EDITOR

Re: An interesting question that came our way regarding a patient taken to the cath lab after an un-witnessed arrest.

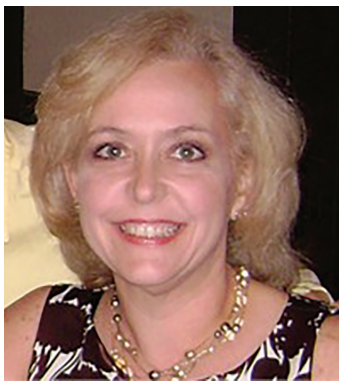
Dr. Kern,

I have a question about the use of opioids in a patient that has an un-witnessed arrest that is brought to the cath lab emergently. The situation involved a patient with an un-witnessed arrest with the patient's family administering CPR. The initial ECG by the EMS team showed asystole. Conversion to a supporting rhythm occurred after administration of ACLS medications. A CT scan was negative. The cardiac angiogram showed only an old occluded RCA. The patient was noted to have discomfort due to assumed pain response. The interventional cardiologist gave verbal order for Benadryl and hydromophone to be administered. The response was as expected and the patient, though unresponsive throughout, seemed more relaxed.
After all was said and done, the nursing staff was questioned about the use of opioids on the patient, because now there needed to be a waiting period to do the necessary testing to determine whether the patient had brain death. I have never heard of such a consideration when working in the cath lab before and wonder what we're getting into in this culture of all considerations for the patient? Is this something new to the emergent patient population that now has to be looked at differently or an overboard response from a non-involved hospital person with a different viewpoint? I would appreciate your response as I am preparing to continue the discussion regarding this perception.
A Director of Cardiac Services

Thanks for your question. I've never heard of a complaint or concern regarding patient care for such a sequence of events. The resuscitated patient may or may not have significant brain damage, and it is unknown whether he senses pain. If in the judgment of the treating physician, the patient would benefit by being more comfortable with Benadryl and morphine, and the result is as you describe, no one should be critical of helping the patient. The delay for assessment of brain death is an irrelevant and greedy concern about reducing length of stay. The person critical of this minor and benign treatment should examine their motives.
MK

CLD BLOGS

Why Do We Do What We Do?



C. Jane Haddox, RT
CVIR Education
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We've all been there. You're on call and come in at 2 am or so. Then, you get up to be back at work at 7 am. You work a busy day with barely a chance to stop for a bladder break, much less lunch. And you go home after 8…10…12 hours to finally rest. Why do we do it to ourselves?

Because of the patients. We've all been there, too, or at least I hope you have. It happened to me again yesterday. The patient came into the room in obvious pain. A little versed and fentanyl later, we got the first guide in and saw the totaled right. The wire went down easily and a stent soon followed. We took a look at the left and the ventricle, and we were done. As we were transferring him to the stretcher for the trip to his room, he asked, "Anybody got any soda?"

This is why we do it! We do it to take people from pain to relief. We do it to take people from illness to normality. We do it to take people from a bad place to a happy place. But it's even more than that. We do it so a father can walk his daughter down the aisle. Or so a grandmother can love on her new grandbaby. We do it so the golfer can go back and make the shot he was in the middle of when the MI hit. We do it to keep families together. We do it so people can have a life again.

And that makes it all worth it. ■