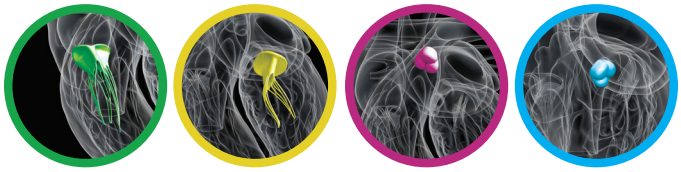


Radiation Protection in Structural Heart Disease Procedures: Strategies to Reduce Exposure

A review of newer radiation protection technologies and efforts to reduce radiation exposure to the operator and interventional echocardiographer.

By Poonam Velagapudi, MD, MS; Lucy M. Safi, DO; Ajay J. Kirtane, MD, SM; and James Hermiller, MD

The number of transcatheter structural interventions is on the rise and will continue to increase as newer therapies are approved by the United States FDA and many others undergo clinical trials. These procedures are complex in nature, requiring an interventional cardiologist and often a cardiothoracic surgeon as operators and an interventional echocardiographer to guide most non–transcatheter aortic valve replacement (TAVR) procedures. Operators may work from either side of the catheterization table or at varying distances from the radiation source, depending on the structural heart intervention and access site used (right vs left; femoral vs subclavian vs transaortic vs transapical vs transcarotid).[1] Fortunately, many structural heart procedures, such as transcatheter mitral and tricuspid intervention and left atrial appendage (LAA) closure, employ right groin access in the majority of cases. Nevertheless, these procedures require the use of large-bore access and closure with a higher risk of complications and additional radiation exposure (RE).

RE to operators and other personnel in the catheterization lab can cause deterministic (related to tissue damage, such as cataracts) and/or stochastic (related to DNA damage, such as cancer) injuries.[2-4] Traditional methods of radiation protection include drop-down lead shields and donning of lead aprons, which can reduce but not eliminate RE. The use of heavy lead aprons carries the risk of orthopedic injuries to operators, which in turn may increase health care expenditure.[5] Operator and staff injuries related to the occupational hazards of the catheterization lab lead to substantial revenue loss. Moreover, the lead apron does not provide whole-body protection—the legs, arms, head, and neck remain exposed, requiring the donning of additional lead gear such as arm and leg guards and hats, which add additional weight. To overcome these issues, alternative radiation protection equipment has been designed, such as the Rampart M1128 (Rampart ic), Protego system (Image Diagnostics Inc.), EggNest Complete system (Egg Medical), and Radiaction system (Radiaction Medical), with unique designs aimed at reducing RE and reducing the burden of lead aprons on the operators. This article discusses some of the newer radiation protection equipment and their use in structural heart procedures.

NEWER RADIATION PROTECTION SYSTEMS

Rampart System

The Rampart system includes several lead panels above the catheterization table, lead curtains below the catheterization table, and lead shielding to cover the patient. The lead panels are attached to a central mast, and this is placed over the patient's body angled at 180° for structural heart cases. Lisko et al randomized 100 elective invasive cardiac procedures, including coronary and transcatheter structural procedures, in

a 1:1 fashion to the Rampart system versus traditional radiation protection.[6] RE was lower with the Rampart system as compared with traditional radiation protection (position 1 [primary operator/fellow]: 0.1 mRem vs 2.2 mRem; $P < .001$; position 2 [secondary operator/attending]: 0.1 mRem vs 3.2 mRem; $P < .001$; and position 3 [catheterization laboratory nurse/technologist]: 0.0 mRem vs 0.8 mRem; $P < .001$). The total body RE was reduced by 95% with the Rampart system in each of these positions. Another advantage of this system is that it reduces the RE 11-fold to areas such as the head and axilla, which are not traditionally protected by lead aprons.

Protego System

The Protego system is a novel lead-shielding technology that uses several radiation shields and drapes strategically placed around the catheterization table to reduce RE to the operator without the need to wear a lead apron. Prior studies have shown that the Protego system significantly reduces RE to the operator in coronary diagnostic and interventional procedures, including chronic total occlusions, compared with the traditional lead shield and lead aprons.[7,8] Rizik et al compared RE in operators using the Protego system versus standard radiation protection with drop-down shield and lead aprons during TAVR procedures. They reported that RE was reduced by 99% with use of the Protego system (thyroid level: 0.08 ± 0.27 µSv vs 79.2 ± 62.4 µSv; $P < .001$; waist level: 0.70 ± 1.50 µSv vs 162.0 ± 91.0 µSv; $P < .001$), and in 60% of the cases using this novel system, RE was 0% while no cases using the standard equipment had 0% RE.[9] Although these findings are observational in nature, the low levels of RE, even in the absence of lead aprons, are reassuring in TAVR procedures, and larger-scale studies involving other structural procedures are needed to ensure that these findings are consistent with other types of structural procedures.

EggNest Complete System

The EggNest Complete system is a radiation protection technology that includes a platform with a mattress, rails, and multiple nonlead equivalent shields that can be adjusted according to the patient's position to reduce radiation scatter for all staff in the room. This system reduces the total room scatter radiation by 91% compared with traditional shielding, with a significant reduction in radiation dose for all camera angles tested and reductions of up to 97% for positions at the head of the table.[10] The system incorporates a ceiling-mounted lead-acrylic shield that provides > 99% reduction in radiation for the operator, scrub tech, and anyone else standing behind the shield. To date, no clinical studies have compared the EggNest system with traditional shielding in transcatheter structural cases to understand whether the benefits of this system are sustained across these cases.

Radiaction System

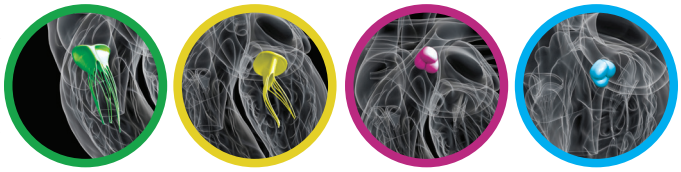
The Radiaction system is a shielding system designed to cover the imaging beam on all sides, thereby blocking scattered radiation at its origin and providing full-body radiation protection to all medical personnel in the lab. It is fitted as an extension to the C arm and comprises two shields, one around the image detector and a second around the x-ray source encapsulating the image beam. The Radiaction system reduced RE to coronary operators by 93% to 94% and to other members of the medical team by 87% to 93% even in the absence of conventional radiation protection.[11] As such, this system is helpful for reducing RE to cardiac imagers in the room who are not usually well protected by other types of radiation protection.

RADIATION EXPOSURE TO CARDIAC IMAGERS

Interventional echocardiographers are exposed to higher radiation levels than implanters,[12] particularly in areas such as the arms, hands, waist, and lower body. RE to the echocardiographer is related to the structural procedure and procedural C-arm angles. Procedures that utilize C-arm angles in the right anterior oblique (RAO) view supply the most RE to the echocardiographer. Transesophageal echocardiography–guided LAA occlusion (LAAO) procedures heavily utilize the RAO caudal projection and offer the highest RE to the echocardiographer. The cusp-overlap view in TAVR also uses the RAO projection during valve deployment.[13] Both LAAO and TAVR procedures are transitioning toward intracardiac echocardiography (ICE) or transthoracic echocardiography (TTE) guidance, respectively. Although ICE imaging reduces RE to the imager, who is now able to be further away from the C-arm, TTE scanning during TAVR procedures still provides RE, especially to the scanning hand. Careful shielding is important when imaging intraprocedurally, although probe manipulation around or through the commercially available shields may be required.

CHALLENGES OF ADOPTING NEWER RADIATION PROTECTION TECHNOLOGIES

Although these newer radiation protection technologies are better than traditional shielding to reduce RE to



operators and other personnel in catheterization labs, their adoption has been slow across the United States. The reasons for this are multifold. First, the upfront costs of acquiring and installing these newer systems are higher than those of the traditional radiation protection equipment. Structural heart cases are performed in the hybrid labs as well as the operating rooms in some hospitals; thus, equipping multiple rooms is costly. Second, operators or cardiac imagers on the left side of the catheterization table or at the head end of the bed are not well protected by most radiation protection technologies, thereby requiring standard shielding. Technologies that provide protection to everyone around the table should be explored further in structural cases. Third, these new radiation protection systems have not been tested in large-scale randomized trials of structural cases, and there is no cost-effective analysis to compare the long-term benefits with traditional radiation protection.

CONCLUSION

The benefits of using newer radiation protection technology in structural heart cases cannot be ignored, and hospitals must make efforts to equip their catheterization labs with them to protect operators and staff from both radiation and orthopedic injuries. Manufacturers of these new radiation protection technologies must work on improving the radiation protection for other operators and cardiac imagers who are at other locations within the procedure room. ■

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