Beating the rays: innovations in radiation protection

Dr Zafraan Zathar MRCP
ST5 Cardiology Registrar
Dudley Group NHS Foundation Trust

Introduction

Radiation exposure is an occupational hazard in cardiology that merits consideration as the sophistication and duration of interventional procedures has increased in recent years. As image-guided structural interventions rise, the risk extends beyond interventional cardiologists to imaging specialists(1). A previous British Cardiovascular Society editorial has described the deleterious effects of radiation and strategies for reduction(2). This editorial will focus on technological innovations in radiation protection, reviewing their feasibility and efficacy (**Table 1**).

Take Home Messages
• Due to the increased complexity of both interventional and structural procedures, there is greater emphasis on cardiologist to take active steps to minimise their occupational exposure. • Recent technological innovations in radiation protection offer several promising options, each with distinct advantages and drawbacks that could affect their integration into existing catheter laboratories. • Potential future challenges include high set up cost, learning curve, ergonomics adjustments for incorporating new technology as well as regulatory and institutional support for their implementation.

Direct operator protection

Real-time dosimetry systems (e.g. Raysafe) have the potential to reduce operator dose by prompting behaviours to optimise procedural technique such as reducing fluoroscopy time or optimising collimation. In the randomised ESPRESSO-Raysafe trial of 700 procedures, radiation exposure was significantly lower for the patient (135 vs. 208µSv) and nurse (0.17 vs. 0.20µSv) in the intervention group(3). Interestingly, no significant difference was noted in radiation exposure for the first (9.0 vs. 9.9µSv) or second operator (1.6 vs. 1.9µSv), who are most vulnerable to cumulative exposure. If procedural techniques are already optimised, real-time dosimetry may cause undue anxiety with minimal benefit.

Radiation protection cabins (e.g. Cathpax®) encase the operator behind a mobile, height-adjustable transparent glass cabin with the aim to reduce radiation exposure and orthopaedic injury from prolonged procedures (**Figure 1**). In a single-centre study, radiation protection cabins were noted to reduce relative radiation exposure by 78% without affecting procedural characteristics such as fluoroscopy time(4). Potential limitations include spatial constraints within the catheterization laboratory, reduced ergonomic efficiency during emergency procedures, and restrictions on the angulation capabilities of fluoroscopy equipment.

Robotic-assisted percutaneous coronary intervention (R-PCI) removes the operator from the radiation exposure altogether. The advantage of R-PCI extends beyond radiation protection to minimising orthopaedic injury, mechanical stability, improved precision and prospect of remote PCI. The R-One robotic system (Robocath) received European conformity approval in 2019 and has been used in a few centres. In the R-EVOLUTION study, use of R-PCI led to an 84.5% reduction in operator radiation exposure(5). However, it is important to note that this radiation protection benefits only the primary operator within the virtual cockpit, leaving the rest of the catheter laboratory team unshielded. As percutaneous procedures continue to grow in both complexity and duration, R-PCI is likely to play an increasingly significant role in the future. Nonetheless, R-PCI currently has several technical limitations compared to manual PCI, including the absence of tactile feedback, the inability to manipulate multiple wires simultaneously, and a longer procedural time.

Scatter radiation reduction

While the aforementioned innovations provide protection for the operator, scatter radiation remains a concern and no protection is extended to the rest of the catheterization laboratory team. RADPAD® is a disposable, lead-free, sterile shield placed directly over patient drapes which can be used to minimise scatter radiation. In a pooled meta-analysis of randomised controlled trial by Bahar et al, RADPAD was associated with significantly lower operator exposure compared to no-RADPAD group (OR -0.9, 95% CI -1.36 to -0.43)(6). This was noted without any difference in total screening time and dose area product (radiation exposure to patients) between the two groups. Whilst this shows that RADPAD can reduce operator radiation exposure, it may influence operator behaviour. In the sham-controlled trial by Vlastra et al, the operator exposure was highest in the sham shield group compared to both RADPAD and no shield group(7). Indeed, it is plausible that the radioprotective drape provide the operator a sense of security which may reduce conventional practices to minimise radiation exposure such as distance from source.

The Radiaction system (Radiaction Medical) aims to reduce scatter by shields assembled on the c-arm around the x-ray tube and image receptor. The shield can be retracted to allow unrestricted angulation of c-arm. Although its efficacy has been confirmed in a feasibility study, no randomized or real-world studies are available to inform clinical practice changes(8). Patient shielding systems such as EggNest XR and PROTEGO surround the patient to reduce scatter. Compared to standard shielding, EggNest

XR has been shown to reduce scatter by 92% whilst PROTEGO reduced scatter by 94%(9,10). The PROTEGO system also reduces operator dose by 99%, achieving "zero" radiation exposure in two-thirds of cases, potentially allowing procedures without protective lead aprons(11).

Conclusion

Radiation protection practices in catheter laboratory have seen little change in recent years. However, emerging innovations hold promise for significantly reducing exposure and moving toward a "lead-free" environment. Each system offers distinct advantages and limitations, requiring careful adaptation to the existing laboratory setup. As these technologies evolve and more data become available, they are poised to become integral to daily practice.

Table 1: Radiation protection devices with their advantages and limitations		
Technology and features	Advantages	Limitations
Real-time dosimetry *Provides immediate visual data on radiation exposure*	Feedback can trigger real time procedural optimisation Useful for trainees as they have less experience and have higher exposure	Negative RCT data for first and second operator May cause undue anxiety to operator
Radiation protection cabin (Cathpax®, Lemer Pax) *2mm lead equivalent cabin with arm cutouts*	Useful in longer procedures with high radiation e.g. CTO, complex ablation Reduces risk of orthopaedic injury	Size (D 910 x W 840 x H 1960 mm) and weight (210kg) reduces manoeuvrability Left sided access may provide ergonomic challenge
Robotic-assisted procedure *Composed of a bedside unit by the patient and an interventional cockpit*	Greater manual precision and manoeuvrability Potential for remote PCI Reduced orthopaedic strain	Learning curve Longer procedural duration Unable to manipulate multiple wires at same time
RADPAD *Sterile disposable shield placed on top of the patient*	Time efficient Can be easily adjusted for radial or femoral access	Cost and environmental impact as they are single use Effectiveness depends on optimal positioning by the operator
Radiaction system *Accessory to the c-arm with flexible fins at the end*	Minimised scatter to all catheter laboratory staff Does not impact clinical workflow	May not be compatible with all c-arm systems No real-world or RCT data on efficacy
PROTEGO *Upper, lower and side shields along with radiation drapes and arm board with radiation drapes*	Potential for a "lead-free" procedure May provide superior radiation protection compared to standard practice	Longer set up may impede use in emergencies e.g. PPCI Reduced maximum bed weight by approximately 45kg
EggNest XR *Carbon fibre base, head and side shields*	Easy to incorporate into existing set up	Cannot be used with biplane systems
CTO = chronic total occlusion; PCI= percutaneous coronary intervention; PPCI = primary percutaneous coronary intervention; RCT= randomised control trial.		

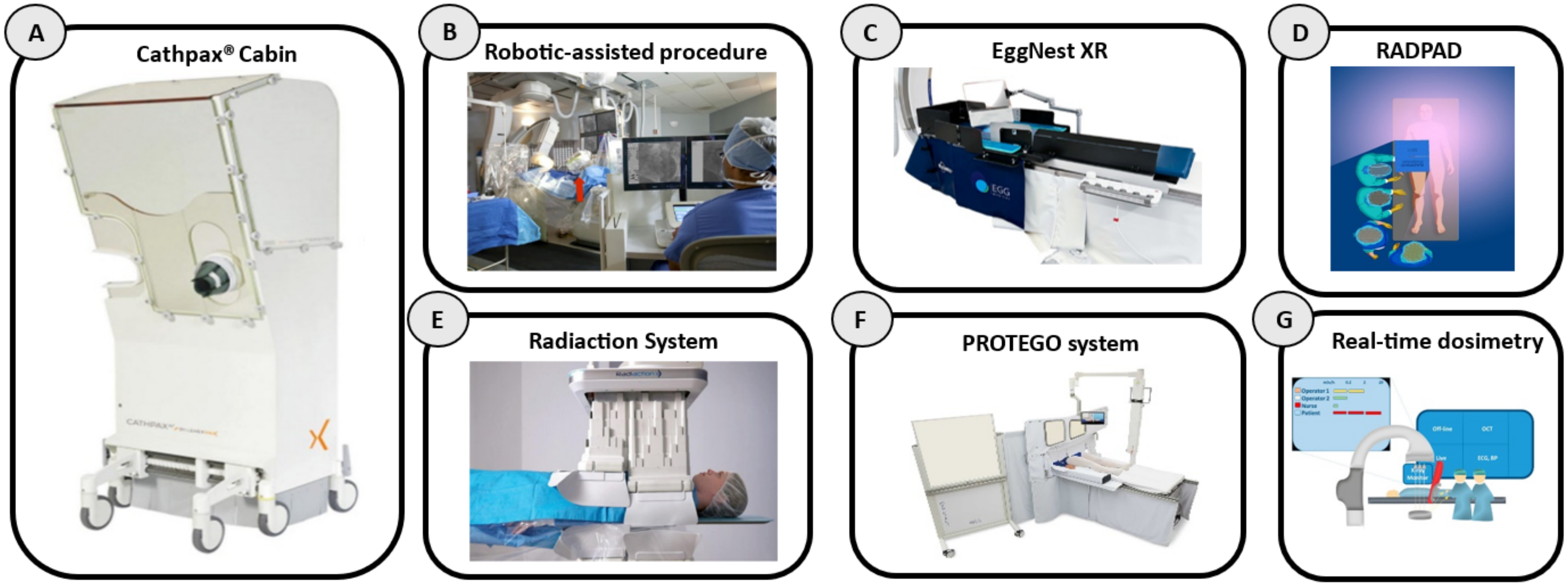

Figure 1: Latest innovations in radiation protection. (A) Radiation protection cabin to encase the operator. (B) Robotic-assisted procedure with the operator in an interventional cockpit. (C) EggNest XR composed of carbon fibre base, rail system, arm board and shielding components (D) Disposable sterile shield placed on top of the patient. (E) Radiaction system incorporated into an existing C-arm. (F) PROTEGO system with patient shielding pads, table shields, mobile side shield, and patient visualisation screens with camera (G) Real-time dosimetry measurement during a procedure

Images adapted from Patel et al (1) and Olschewski et al (3) through Creative Commons Attribution (CC BY) license.

Reference

1. Patel AH, Patel V, Tang Y, Shah S, Tang G, Kern MJ. Implementing a 'Lead [Apron]-Free' Cardiac Catheterization: Current Status. Curr Cardiol Rep. 2024 Sep;26(9):1021–9.

2. Hinton, Jonathan. British Cardiovascular Society Editorials. 2020. Radiation safety in the cath lab: does it still matter? Available from: https://bcs-web.squiz.cloud/resources/editorials/articles/radiation-safety-in-the-cath-lab-does-it-still-matter

3. Olschewski M, Ullrich H, Brandt M, Steven S, Ahoopai M, Blessing R, et al. Effectiveness of a Real-Time X-ray Dosimetry Monitor in Reducing Radiation Exposure in Coronary Procedures: The ESPRESSO-Raysafe Randomized Trial. J Clin Med. 2021 Nov 17;10(22):5350.

4. Gutierrez-Barrios A, Angulo-Pain E, Noval-Morillas I, Cañadas-Pruaño D, Lastra IA, Gheorghe L, et al. The radioprotective effect of the Cathpax® AIR cabin during interventional cardiology procedures. Catheter Cardiovasc Interv. 2021 May 12;ccd.29773.

5. Durand E, Sabatier R, Smits PC, Verheye S, Pereira B, Fajadet J. Evaluation of the R-One robotic system for percutaneous coronary intervention: the R-EVOLUTION study. EuroIntervention. 2023 Apr;18(16):e1339–47.

6. Bahar AR, Khanal R, Hamza M, Goru RK, Shafiq A, Haider MZ, et al. Assessing the Efficacy of RADPAD Protection Drape in Reducing Radiation Exposure to Operators in the Cardiac Catheterization Laboratory: A Systematic Review and Meta-Analysis. Cureus [Internet]. 2024 Apr 28 [cited 2024 Nov 7]; Available from: https://www.cureus.com/articles/232108-assessing-the-efficacy-of-radpad-protection-drape-in-reducing-radiation-exposure-to-operators-in-the-cardiac-catheterization-laboratory-a-systematic-review-and-meta-analysis

7. Vlastra W, Delewi R, Sjauw KD, Beijk MA, Claessen BE, Streekstra GJ, et al. Efficacy of the RADPAD Protection Drape in Reducing Operators' Radiation Exposure in the Catheterization Laboratory: A Sham-Controlled Randomized Trial. Circ: Cardiovascular Interventions. 2017 Nov;10(11):e006058.

8. Laish-Farkash A, Harari E, Finkelstein A, Sheinman G, Rahkovich M, Kogan Y, et al. A novel robotic radiation shielding device for interventional cardiology procedures. EuroIntervention. 2022 Jun;18(3):262–6.

9. Wilson R, Gainor J, Valeti U, Montague J, Wilson B. TCT-248 A New Device to Markedly Reduce Cardiac Cath Lab Radiation Levels. Journal of the American College of Cardiology. 2018 Sep;72(13):B103.

10. Dixon SR, Rabah M, Emerson S, Schultz C, Madder RD. A Novel Catheterization Laboratory Radiation Shielding System: Results of Pre-Clinical Testing. Cardiovascular Revascularization Medicine. 2022 Mar;36:51–5.

11. Rizik DG, Gosselin KP, Burke RF, Goldstein JA. Comprehensive radiation shield minimizes operator radiation exposure in coronary and structural heart procedures. Cardiovascular Revascularization Medicine. 2024 Mar;S155383892400068X.