



## Training/Practice

### Contemporary Issues in Cardiology Practice

# Ionizing Radiation in Interventional Cardiology and Electrophysiology

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#### ABSTRACT

Fluoroscopy-guided procedures constitute a major part in the practice of cardiology. These procedures are also a source of human-made ionizing radiation. Although the benefits of performing the procedure surpass the radiogenic risks in most cases, the risks are not negligible. Exposure to ionizing radiation may lead to tissue injuries and potential increase in risk of cancer. Both patients and operating physicians are exposed to these risks in variable degrees. The institution of radiation safety practices alone significantly reduces radiation exposure. Beyond the interventional laboratory, increasing physicians' awareness to health-related risks of ionizing radiation is crucial in reducing unnecessary testing and increases receptiveness to patient risks. Incorporating the radiogenic risks of a future procedure in patient-informed consent also increases patients' awareness to potential consequences. Innovation in imaging technology resulted in a plethora of alternate modalities. Electroanatomical mapping, magnetic navigation systems, robotic and magnetic resonance imaging (MRI)-assisted techniques are examples of clinically used modalities that limit the exposure of

Innovation in minimally invasive procedures has changed the practice of cardiology. Nonsurgical interventions, such as chronic total occlusion percutaneous coronary intervention (CTO-PCI), transcatheter valve interventions, cardiovascular implantable electronic devices, and ablation of complex arrhythmias, have become the standard of care. These

#### RÉSUMÉ

Les interventions pratiquées sous guidage fluoroscopique font partie intégrante de la pratique en cardiologie. Ces interventions sont également une source de rayons ionisants d'origine humaine. Si les bienfaits de l'intervention l'emportent sur les risques radiogéniques dans la plupart des cas, ces risques ne sont pas négligeables. L'exposition au rayonnement ionisant peut provoquer des lésions tissulaires et augmenter potentiellement le risque de cancer. Les patients comme les médecins qui pratiquent l'intervention sont exposés à ces risques à des degrés variables. La mise en place de pratiques de sûreté radiologique à elle seule réduit nettement l'exposition au rayonnement. Il est impératif qu'en dehors du laboratoire interventionnel, les médecins soient de plus en plus nombreux à prendre conscience des risques pour la santé que représentent les rayons ionisants, afin de réduire les examens inutiles et de mieux sensibiliser aux risques pour les patients. Intégrer les risques radiogéniques associés à une intervention future au processus d'obtention du consentement éclairé des patients permet également de sensibiliser ces

procedures are generally performed under fluoroscopy guidance, which is a major source of ionizing radiation. Knowledge about ionizing radiation and its health-related risks is often scarce among cardiologists. In this article, we will discuss the implications of ionizing radiation and highlight the latest innovative techniques and measures to reduce exposure in interventional cardiology and electrophysiology.

#### Ionizing Radiation and Potential Risks

Radiologic tests are a major source of human-made ionizing radiation. The amount of ionizing radiation transmitted to the patient or the effective dose (ED), is variable among different imaging modalities. Measurement of the ED

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patients and operating physicians to radiation. Documentation of patients' exposure in their medical records is essential. Tracking of patients' cumulative exposure can be implemented at an institutional level. Identifying patients with the highest exposure would help shed light on a blind spot in our current practice, as the implications are unclear.

allows the assessment of the global personal risk.<sup>1</sup> Table 1 lists the estimated ED of the most common cardiac tests and procedures.

The biologic effects of ionizing radiation are divided into tissue reactions and stochastic effects.<sup>1</sup> Tissue reactions, formerly known as deterministic effects, such as skin injuries and cataracts, are directly proportional to the dose of ionizing radiation delivered.<sup>1</sup> Skin reactions are uncommon among the operators and occur mostly in patients undergoing lengthy procedures.<sup>1</sup> Cataracts develop over an extended period among operators.<sup>1</sup> On the other hand, the stochastic effect, described by the "linear-no-threshold" model, indicates that the probability of developing cancer is present at any amount of exposure.<sup>1</sup> Patients and operators are both exposed to ionizing radiation during the procedure, but the distribution and degree of exposure is significantly different. Professionals working in a fluoroscopy environment for most of their adult lives have a lifetime time risk of developing cancer estimated to be 0.62 % for men and 1.02 % for women.<sup>1</sup> From a patient's perspective, the predicted attributable cancer risk from ionizing radiation exposure is extremely sensitive to gender and age.<sup>1</sup> One of 100 patients is at risk of developing solid cancer or leukemia if exposed to 100 mSv.<sup>1</sup>

### Occupational exposure

Interventional cardiologists and electrophysiologists are among the most highly exposed physicians ionizing radiation.<sup>1</sup> Several international societies have issued guidelines on

**Table 1. Typical radiation doses of common cardiac imaging compared with chest x-ray and annual background radiation<sup>1,3</sup>**

Study	Typical effective dose estimate (mSv)
Chest x-ray	0.02
Annual average background radiation	3
Cardiac coronary computed tomography	5-20
Sestamibi myocardial perfusion imaging	11-18
Diagnostic electrophysiological study	0.1-3.2
Pacemaker or implantable cardioverter defibrillator placement	1.4-17
Cardiac resynchronization therapy device implantation	2.2-95
Radiofrequency ablation of arrhythmia	1-25
Diagnostic coronary angiogram	2-20
Percutaneous coronary intervention	5-57

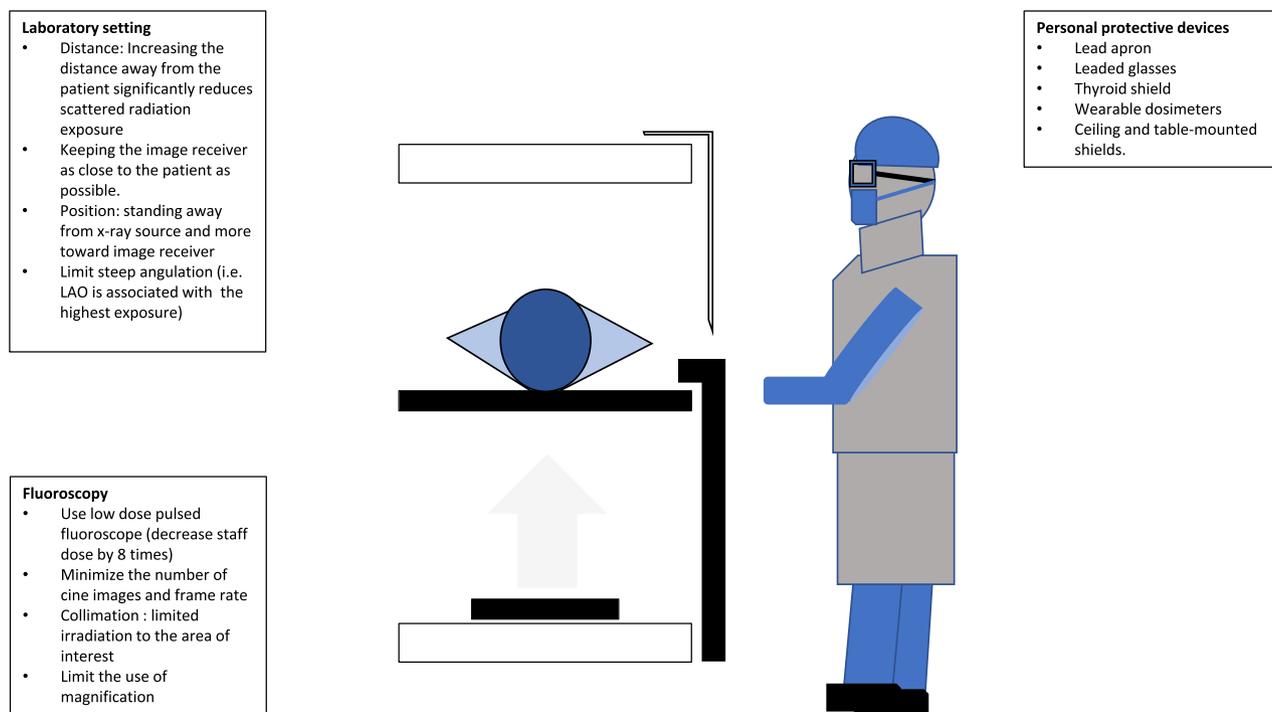
derniers aux conséquences possibles. L'innovation technologique en imagerie s'est traduite par une pléthore de modalités de recharge. Le mappage électro-anatomique, les systèmes de navigation magnétique, les techniques robotiques ou assistées par IRM (imagerie par résonance magnétique) sont des exemples de modalités utilisées en clinique qui limitent l'exposition des patients et des médecins au rayonnement. Il est impératif de documenter l'exposition des patients dans leur dossier médical. Le suivi de l'exposition cumulative des patients pourrait être mis en œuvre à l'échelle des établissements. Repérer les patients dont l'exposition est la plus élevée pourrait contribuer à mettre en lumière une zone d'ombre dans notre pratique actuelle, dont les implications ne sont pas claires.

ionizing radiation in cardiovascular imaging. The goals of such statements are to increase physicians' awareness of ionizing radiation associated risks and means to keep exposure as low as reasonably achievable (ALARA).

In the laboratory, protective equipment must be worn during fluoroscopy use to protect the operator from scattered ionizing radiation.<sup>1</sup> They prevent the absorption of about 95% of scatter radiation.<sup>1</sup> Dosimeters worn by operators regularly monitor the cumulative dose of occupational ionizing radiation. The measured limit of occupational exposure is an effective dose of 20 mSv per year averaged over 5 years and not exceeding 50 mSv per year in any given year.<sup>1</sup> Increasing awareness and institution of radiation-safety practices is an important aspect in reducing ionizing radiation exposure. A summary of the main radioprotective measures is illustrated in Figure 1.

### Innovation in Imaging Techniques

The quest for alternative imaging methods with minimal fluoroscopy exposure yielded a plethora of innovative techniques. In electrophysiology, the emergence of imaging techniques, such as 3-dimensional electroanatomical mapping (3D-EAM) and intracardiac ultrasound (ICE), has significantly reduced fluoroscopy time during ablation procedures.<sup>2</sup> The EAM system creates an electromagnetic field that generates a 3D model of the desired cardiac structure and allows tracking and manipulation of the catheters without using fluoroscopy.<sup>2</sup> The most common mapping systems are the CARTO system (Biosense-Webster, Los Angeles, CA) and Ensite-NavX system (Abbott, SJM, St Paul, MN).<sup>2</sup> These mapping systems acquire electrograms by a small number of electrodes in the introduced catheter. In addition, the Rhythmia mapping system (Boston Scientific, Inc, Cambridge, MA), used in conjunction with a unique 64-electrode basket catheter that allows rapid recording of electrograms in high-resolution maps, allows short procedure time. Minimal cinefluoroscopy is the hallmark of the MediGuide system (St Jude Medical Inc, St Paul, MN).<sup>2</sup> It permits real-time navigation of the catheters on prerecorded cinefluoroscopy images. Mallet et al. showed a consistent reduction in fluoroscopy time in atrial fibrillation/atrial flutter (AF/AFL) ablation procedures by 61% and 90% using the MediGuide system with no difference in the total procedure time.<sup>2</sup> More recently, real-time cardiac MRI-guided ablation showed promising results in the development of zero fluoroscopy ablation.<sup>3</sup>



**Figure 1.** Strategies to reduce ionizing radiation exposure in fluoroscopy-guided procedure.<sup>1,3</sup>

Robotic navigation systems have been used in robotic-assisted PCI.<sup>4</sup> The interventionalist manipulates the catheters via a control console in a remote shielded environment.<sup>4</sup> At the bedside, a robotic is used to insert wires, balloons, and stents.<sup>4</sup> The CorPath 200 and CorPath GRX (Corindus Vascular Robotics, Waltham, MA) are 2 robotic systems that have been used in PCI of simple and complex lesions with a demonstrated feasibility and safety equivalent to manually performed procedures.<sup>4</sup> More innovative techniques are being developed in the electrophysiology field. Noninvasive stereotactic arrhythmia radioablation (STAR) is an example of using localized radiotherapy for ablation of ventricular arrhythmias.<sup>5</sup> The experience with this modality is at the initial phase; however, a small feasibility study showed successful ablation of refractory ventricular arrhythmias in a relatively short duration with no ionizing radiation exposure to the electrophysiologist.<sup>5</sup>

**Patient-centred imaging**

Efforts to reduce ionizing radiation exposure are not limited to the interventional laboratory. A judicious approach to ionizing radiation exposure entails education of physicians, informed patient consent, documentation and tracking of exposed patients.

**Education and consent.** There is no doubt that imaging tests are the cornerstone in the management of cardiac diseases and—in most cases—lifesaving. Increasing physician awareness of the radiogenic effects is essential. The acquired knowledge may raise the receptiveness to limit unnecessary testing and encourage the use of an alternate imaging modality, if possible.

Pursuing an intervention that uses ionizing radiation should be preceded with a discussion on the benefits and potential risks. The informed consent must also include the potential stochastic effects and tissue reactions.<sup>1,3</sup> The discussion should not convey fear and minimal medical jargon should be used. Thus, the estimated effective dose of a particular test must be converted to an equivalent number of chest x-rays or natural background radiation.<sup>1,3</sup>

**Documentation and tracking.** Patients are exposed to myriad imaging tests. Although the radiogenic risks of a single test are small, the cumulative dose of multiple tests over time may have potential risks. Documentation and tracking of previous tests would identify those with the highest exposure.

The dose of ionizing radiation transmitted to patients must be documented in their medical records. Most x-ray systems report this value in a kerma-area product (KAP, Gy.cm2) or dose-area product (DAP, Gy.cm2).<sup>3</sup> The interpretation of the reported values may not be intuitive for most physicians. Thus, a simplified equation can be used to convert the total amount of ionizing radiation exposure to the ED. Multiplying the DAP by a conversion factor is a simple way of estimating the ED ( $ED [mSv] = DAP \times 0.2$ ).<sup>3</sup>

Tracking patients' exposure has an established benefit in the acute setting, as patients exposed to levels above a threshold limit are at risk of developing skin injuries.<sup>1</sup> Those patients receive an initial assessment and a scheduled follow-up to examine the affected area, as macroscopic manifestations appear weeks after the injury.<sup>1</sup> However, tracking of long-term cumulative exposure is less practiced. The reason behind that may be challenges in the collection and interpretation of the data.

The implications of detecting individuals with the highest exposure are also unclear. At an institutional level, documentation of the ED of every procedure is an important first step in tracking patients' cumulative exposure. Regular addition of the ED of subsequent tests would allow the cumulative dose of the patient to be displayed in the electronic medical record (EMR) in addition to the dose of the current test. This information can be made available within the study report. Sharing the data via a provincial or national EMR would provide physicians and health authorities with the necessary information for the development of future strategies. Such information would also play a role in determining the implications of testing patients with established cancer diagnoses or who are undergoing radiotherapy.

### Conclusion

Fluoroscopy-guided procedures, among other imaging modalities, have become an essential part in the practice of cardiology. Although the risks of exposure to ionizing radiation from a single test are small, the cumulative exposure from multiple tests over time may have detrimental consequences. Limiting unnecessary testing can be established by increasing patient and physician awareness of the effects of ionizing radiation. Establishment of institutional policies on documentation and tracking of ionizing radiation exposure may shed light on a blind spot in our current practice.

### Disclosures

The authors have no conflicts of interest to declare.

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