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Optimizing Radiation Dose and Patient Follow-Up in Fluoroscopy-Guided Interventions: Roles of Radiology Professionals, Medical Physicists, and Nurses

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Abstract

Background: Fluoroscopy-guided interventions offer therapeutic benefits but can expose patients and staff to substantial radiation. Safety requires appropriate imaging and reliable follow-up after elevated exposure.
Methods: This review synthesizes selected guidance, dosimetric investigations, and clinical studies published by 31 December 2024, examining dose interpretation, optimization, follow-up, and professional responsibilities.
Results: Peak skin dose, reference air kerma, kerma–area product, and fluoroscopy time describe different aspects of exposure. Equipment assurance, suitable pulse rates, collimation, and imaging geometry support optimization. Notification and follow-up thresholds prompt assessment without establishing that injury has occurred. Radiology professionals implement acquisition protocols; medical physicists evaluate equipment and dosimetry; nurses connect preparation, observation, education, and follow-up. Evidence supports individual technical and communication interventions, while the effectiveness of a complete integrated pathway remains less directly established.
Conclusion: Radiation protection extends from justification through documented clinical follow-up. Qualified personnel, clear responsibilities, meaningful dose records, and assessment of image adequacy and patient outcomes provide a practical framework for safer care.

Keywords: fluoroscopy; radiation protection; medical physics; radiologic technologists; nursing; patient follow-up.

Introduction

Fluoroscopy-guided interventions enable clinicians to navigate instruments and treat disease while viewing anatomy in real time. Their safety depends on obtaining sufficient information for the clinical task while avoiding unnecessary radiation. International radiation-protection guidance places justification and optimization within a wider system of professional responsibility, equipment assurance, and patient-centered communication. A low dose has limited value if inadequate visualization compromises treatment or creates additional procedural risk.[1]

Safety responsibilities extend beyond the operator and the imaging department. Fluoroscopy is used in interventional radiology, cardiology, operating theatres, gastroenterology, and other services, where training and monitoring arrangements may differ. Radiology professionals, medical physicists, and nurses contribute distinct capabilities that must remain connected across these locations. The central organizational challenge is to ensure that a dose recorded during an intervention leads to an appropriate clinical response when the patient has already left the procedural unit.[2]

This review examines the evidence available by the end of 2024 and proposes an integrated approach to dose optimization and follow-up. It addresses the responsibilities of all three professional groups without assuming that a professional title alone establishes competence to perform every fluoroscopic task.

Review approach

A targeted literature review was undertaken using PubMed/Europe PMC records, publisher sources, and publications from international and professional organizations. Sources were selected for relevance to fluoroscopic dosimetry, equipment performance, procedural techniques, nursing communication, and patient follow-up. Eligibility was restricted to material published by 31 December 2024; later revisions were not used to describe the historical evidence base. Bibliographic details were checked against indexed records or official publications. This is a selective clinical synthesis, without pooled effect estimates or a claim of exhaustive systematic retrieval. Recommendations derived from consensus guidance are distinguished from findings of comparative clinical studies and from the proposed workflow presented here.

Radiation effects and interpretation of dose information

The immediate radiation concern during lengthy interventions is a tissue reaction, particularly injury to the irradiated skin. Severity and timing depend on absorbed dose, the area exposed, previous irradiation, and individual susceptibility. Erythema, hair loss, and more serious tissue injury may emerge after a delay, so an uncomplicated recovery-room assessment cannot exclude a later reaction. Repeated irradiation of the same skin region requires particular attention even when the skin initially appears normal.[3]

Dose information also has important limitations. Reference air kerma is an equipment-reported quantity at a defined reference location, rather than a direct measurement of the highest absorbed dose in the patient's skin. In a study of 41 embolization procedures, differences between indirect estimates and measured peak skin dose depended partly on source-to-patient distance and the distribution of imaging events. Accordingly, apparent precision on a dose display should not be confused with equally precise knowledge of tissue exposure.[4]

Peak skin dose estimates require information about beam geometry, overlapping fields, table attenuation, backscatter, and patient position. Radiation dose structured reports can support reconstruction, but the quality of the estimate depends on the completeness and interpretation of the underlying information. Medical physicists should state material uncertainties when reporting reconstructed doses. Table 1 summarizes the quantities used in practice and the interpretation each can reasonably support.[5,6]

Table 1. Radiation quantities and their appropriate clinical interpretation

Quantity	Useful application	Important limitation
Peak skin dose, Gy	Estimates the largest absorbed dose in a localized skin region; supports assessment of tissue-reaction risk.	Often reconstructed rather than directly measured; geometry and calculation assumptions influence uncertainty.

Quantity	Useful application	Important limitation
Reference air kerma, Ka,r, Gy	Practical monitoring index for intraprocedural notifications and postprocedural assessment.	Defined at a reference point; it is not identical to peak skin dose.
Kerma–area product, KAP, Gy·cm²	Describes radiation output integrated over beam area; useful for procedure comparisons and exposure auditing.	Does not identify the most heavily irradiated skin site or independently establish an individual cancer risk.
Fluoroscopy time, min	Records one component of imaging use and helps assess workflow.	Omits variation in dose rate and the contribution of acquisition runs; it cannot stand alone as a skin-dose measure.

Preparation and individualized procedural planning

Radiation planning begins before the first exposure. Relevant information includes the intended intervention, anticipated technical difficulty, previous procedures involving the same region, and factors that may increase tissue sensitivity. Reviewing existing images may prevent unnecessary repeat acquisition. For procedures likely to involve substantial exposure, the consent discussion should explain why fluoroscopy is needed, how exposure will be managed, and why delayed contact or examination may be necessary. This discussion should remain proportional to risk and avoid presenting every intervention as equally hazardous.[7,8]

Pregnancy requires individualized evaluation rather than automatic cancellation of necessary treatment. The referring clinician and proceduralist assess urgency, alternatives, and the expected benefit; the medical physicist assists with anticipated or retrospective fetal-dose assessment where appropriate. Radiology staff implement the agreed field limitation and acquisition strategy, while nurses support sensitive history-taking and communication. Ultrasound or magnetic resonance imaging may be suitable alternatives for selected clinical questions, but neither universally replaces fluoroscopic guidance. Pregnancy-related decisions require the clinical context and a documented multidisciplinary plan.[9]

An effective preparation process also identifies who will monitor the dose display, communicate notifications, archive the final report, and arrange follow-up. Assigning these tasks before the procedure is a practical safeguard against the assumption that another team member has completed them.

Equipment assurance and imaging optimization

Medical physicists contribute at equipment selection, acceptance testing, protocol development, and ongoing performance evaluation. AAPM Task Group 272 provides a structured approach for assessing complex interventional systems, general fluoroscopy units, and mobile C-arms. Relevant evaluations connect radiation output with image quality and system behavior; an equipment check limited to whether an image appears on the screen is insufficient for a comprehensive safety program.[10]

The qualified medical physicist also identifies which activities require direct professional assessment and which can be performed under suitable supervision. Routine checks by trained radiology staff complement this role by detecting changes during everyday use. Suspected equipment faults, unexpected dose readings, or deterioration in image quality should enter a documented escalation process. Manufacturer maintenance and application support contribute technical information but do not replace the facility's responsibility for clinical quality assurance.[11]

Radiology professionals translate optimized protocols into consistent image acquisition. Practical measures include using appropriate collimation, minimizing unnecessary magnification and acquisition runs, keeping the detector suitably close to the patient, and maintaining favorable source-to-skin geometry within procedural constraints. Phantom investigations demonstrate that combinations of operational

choices can substantially alter skin dose; changing one setting while overlooking other geometry or exposure-control factors can produce misleading expectations. Optimization should therefore examine the imaging chain as a whole.[12]

Reduced pulse or frame rates are useful when the resulting temporal information remains adequate. A randomized study of transradial coronary angiography and intervention found lower patient and operator exposure with 7.5 rather than 15 frames per second under its configured protocols. This supports testing lower-rate settings for appropriate tasks, but does not establish one rate for every intervention. Device motion, patient anatomy, procedural phase, and system processing can require different settings. Image adequacy and technical success should accompany dose measurements when a protocol changes.[13]

Changing the projection merely to distribute exposure across the skin can be counterproductive. Steeper oblique geometry may increase radiation output and bring the skin closer to the source; any such strategy requires assessment of its actual effect on skin dose.[14]

Radiology professionals should therefore communicate deterioration in visibility promptly, while the proceduralist determines whether additional imaging is clinically necessary. Avoiding exposure does not justify continuing instrument manipulation without adequate guidance. Conversely, a higher-dose mode should not persist merely because it was required briefly during an earlier, more demanding step.

Children, repeated procedures, and technically difficult cases

Children with congenital heart disease may require multiple interventions over many years. Pediatric imaging recommendations emphasize size-appropriate protocols, suitable equipment configuration, and preservation of the information necessary for diagnosis and treatment. Reducing avoidable exposure is particularly relevant to this cumulative care pathway; however, lifetime cancer-risk estimates are model-dependent and should not be presented as predictions for a specific child.[15]

A randomized pediatric catheterization study showed that selected antiscatter-grid removal strategies could reduce exposure while retaining sufficient image quality in its population. Such findings require local assessment of patient size, equipment, and clinical task rather than indiscriminate removal of grids. A 2024 observational comparison likewise associated a collection of dose-limiting practices and newer technology with lower exposure across many procedure categories. Because settings, eras, and institutions differed, the reduction cannot be assigned solely to one profession or one technical change.[16,17]

Large body habitus, steep projections, complex anatomy, and repeated treatment may create additional challenges. Their presence should prompt a plan for adequate visualization, exposure monitoring, and possible staged treatment when clinically appropriate. The decision to stage or continue remains a clinical benefit–risk judgment, not an automatic response to a numerical display.[18]

Professional coordination during the intervention

Nursing responsibilities include preparation, assessment, observation, support of the patient's comfort, and recognition of deterioration within the nurse's authorized scope. When moderate sedation is used, appropriate monitoring, dedicated attention, and the capacity to recognize and rescue unintended deeper sedation remain essential. Radiation protection arrangements should not obstruct airway access, monitoring, or urgent care. The dose observer and the person responsible for continuous clinical monitoring should be explicitly identified so that attention is not silently diverted from the patient.[19]

Communication can itself influence occupational exposure. In a prospective controlled study involving 93 interventional radiology procedures, nurses who notified the operator before approaching the patient received lower radiation exposure than those who did not. This finding supports coordination of bedside tasks with opportunities to pause irradiation when clinically feasible. It does not justify delaying an urgent assessment or assuming that a verbal alert makes shielding unnecessary.[20]

Professional scope must be specific to the modality and task. An MRI technologist can contribute imaging knowledge, patient preparation, and coordination of appropriate alternative examinations, but MRI training alone does not confer competence to operate a fluoroscopy unit. Additional education, supervised practice, and institutional authorization are necessary where duties cross modalities. The same principle applies when nurses or radiographers move between departments that use different imaging systems.[21]

Table 2 presents a proposed allocation of work across the care pathway. These responsibilities synthesize professional guidance; they are not a validated staffing model or evidence that the combined pathway independently reduces complications.

Table 2. Proposed responsibilities across an integrated fluoroscopy safety pathway

Professional group	Core contribution	Handover or escalation responsibility
Radiology professionals	Prepare imaging equipment; select approved protocols; optimize geometry and collimation; monitor and preserve dose data.	Communicate dose notifications and image-quality concerns; transfer the final dose report and relevant geometry information.
Medical physicists	Commission and evaluate equipment; advise on protocol performance and dose indices; assess skin-dose estimates and uncertainty.	Interpret unusual exposures; recommend technical changes and assist clinicians with risk-informed follow-up planning.
Nurses	Prepare and observe the patient; coordinate bedside activity; provide understandable discharge education and planned follow-up contact.	Escalate clinical deterioration or possible delayed skin changes; document contact attempts and clinical referrals.
Procedural clinician and clinical service	Justify and conduct the intervention; balance technical success against all procedural risks; diagnose and manage complications.	Own the clinical follow-up plan and specialist referral; ensure that findings return to the procedural team.

Notifications, documentation, and follow-up

Dose notifications should prompt reassessment at a safe point in the procedure. AAPM's 2022 guideline describes an initial notification at 3 Gy reference air kerma, followed by notifications at additional 1 Gy increments, with modification for local practice and patient factors. Suggested substantial radiation dose levels are 5 Gy reference air kerma or 3 Gy peak skin dose. These are operational triggers for further action: exposure below a trigger is not an absolute guarantee of safety, and exposure above it does not establish injury. Necessary treatment should not be stopped solely because a notification level is reached.[14]

Documentation should retain the procedure identification, available dose indices and units, and sufficient information to support subsequent interpretation. The final dose report belongs in an accessible clinical record rather than solely in a console archive. Relevant notifications, the operator's response, and the follow-up arrangement should be traceable. Consistent terminology reduces confusion when patients move between radiology, cardiology, surgical services, and outpatient care.[22]

For patients exceeding an institutional trigger, ICRP guidance supports follow-up approximately two to four weeks after the intervention to identify potential skin injury. Earlier review is appropriate if symptoms occur; later assessment may be needed because manifestations can be delayed. Patients should receive clear contact information and advice about which skin region to observe, with assistance from a caregiver when the area is difficult to inspect. The timing and intensity of follow-up should reflect exposure, prior irradiation, and clinical circumstances.[23]

A nurse-led contact can ask about new redness, hair loss, itching, pain, or an evolving lesion and arrange clinical evaluation when indicated. It should not label every rash as radiation injury or exclude injury

solely because an initial telephone review is reassuring. Persistent or concerning lesions require examination by the responsible clinician and appropriate specialist input. Clinical assessment and physicist-supported exposure reconstruction should inform each other, especially when the location or timing of a lesion is atypical.[24]

The proposed pathway should record unsuccessful contact attempts and identify who takes the next action. A final entry should state whether follow-up was completed, further examination was arranged, or the patient could not be reached. This makes continuity of care measurable and gives future treating teams a usable account of the exposure and its clinical assessment.

Occupational protection and service improvement

Patient-dose optimization often reduces scatter, but staff protection also requires correctly positioned ceiling-mounted and table-side shields, appropriate protective clothing, personal dosimetry, and attention to distance. Nurses who must remain near the patient may need movable protection compatible with observation and access. Protective devices should not obstruct essential care or enter the primary beam in ways that alter exposure-control behavior. Dosimeter review should investigate unexpectedly low readings as well as high readings, since missing or incorrectly worn dosimeters can obscure the actual exposure pattern.[25]

Service evaluation must distinguish individual follow-up triggers from diagnostic reference levels. Reference levels help assess representative groups of comparable examinations; they are not dose limits or alarm settings for individual patients. Comparisons should consider procedure type, patient size, and clinical complexity. Persistently high values warrant investigation, while unusually low values require confirmation that image quality and clinical performance remain adequate.[26]

Audits can compare dose distributions and the proportion of procedures requiring additional assessment, rather than focusing exclusively on an average. This approach recognizes that complex interventions have substantial clinical variability. A service receiving difficult referrals should not be judged solely against a less complex case mix; equally, complexity should not become an unexamined explanation for every high exposure.[27]

Electronic dose-monitoring systems can support these activities when patient identifiers, units, equipment mapping, and data completeness are reliable. The underlying records should retain relevant fluoroscopy and acquisition events, including separate information from biplane systems when available. Automatic capture facilitates review but does not establish that someone has acted on a notification or contacted the patient.[6]

A practical dashboard could combine dose-report completeness, documented notification responses, completion of indicated follow-up, equipment actions, and image-quality or procedural outcomes. This is an implementation proposal requiring local validation. Its purpose is to make safety responsibilities observable while preserving professional judgment and avoiding incentives to lower dose at the expense of necessary treatment.

Limitations and priorities for further research

The evidence combines professional consensus, technical experiments, randomized evaluations of selected practices, and observational improvement studies. Results from coronary or pediatric catheterization cannot automatically be transferred to every fluoroscopic intervention. Equipment generation, procedure complexity, operator technique, and definitions of exposure differ between reports. Some guidance remains foundational despite its age, while newer technology may require additional local evaluation.

The complete multidisciplinary pathway described here has not been established as a single intervention with a quantified effect on skin injury or long-term outcomes. Future evaluations should measure exposure and clinical adequacy together, document delayed follow-up reliably, and assess barriers to communication across departments. Studies should also distinguish reduced recorded dose from better patient outcomes and report uncertainty in skin-dose estimation.

Conclusion

Optimizing radiation dose in fluoroscopy-guided interventions requires a continuous care process that begins with a justified procedure and continues after the patient leaves the imaging suite. Appropriate equipment settings, imaging geometry, and exposure monitoring are essential, but their value depends on the ability of the clinical team to interpret the information and act on it. A numerical dose report becomes useful patient-safety information when it is linked to a documented decision and a reliable follow-up arrangement.

Radiology professionals contribute practical control of acquisition and the integrity of imaging records. Medical physicists provide the measurement, equipment evaluation, and uncertainty assessment required to interpret exposure and improve protocols. Nurses connect procedural preparation, clinical observation, bedside communication, and patient education with subsequent contact and escalation. These responsibilities should be assigned according to demonstrated competence and local professional scope, with the procedural clinician retaining responsibility for clinical decisions and management of complications.

The evidence available through 2024 supports several components of this approach, including task-appropriate reductions in imaging rates, selected pediatric optimization techniques, and communication practices that reduce avoidable staff exposure. It also supports caution: operational dose triggers are not predictions of injury, and a successful low-dose protocol must preserve adequate visualization and treatment quality. Institutions should therefore assess dose distributions, image adequacy, completion of follow-up, and clinical outcomes together. A coordinated program can make responsibilities clearer and reduce missed opportunities for prevention and recognition, while further research is needed to determine the patient-level benefits of the complete integrated model.

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