Comparative Evaluation of Radiation Dose and Image Quality in Two Cardiac Fluoroscopy Systems with Distinct Image Processing Algorithms

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ABSTRACT

Purpose: To quantitatively compare radiation dose output and image quality performance between two cardiac fluoroscopy systems operated under matched exposure conditions, and to assess the impact of proprietary image processing on low-contrast detectability.

Methods: A Leeds TOR 18-FG fluoroscopy phantom was sandwiched between 18 cm of polymethyl-methacrylate (PMMA) and imaged on two clinical cardiac catheterization systems (Fluoroscopy System 1 and Fluoroscopy System 2). Each system was operated in its respective low- and high-dose clinical fluoroscopy modes. Comparable dose settings were identified by matching air kerma rates measured at the FDA reference point. For each condition, last-image-hold frames were evaluated subjectively by counting visible contrast-detail targets and line-pair groups. Objective measurements were performed by calculating contrast and noise from standardized regions of interest for each contrast disc, enabling construction of contrast-detail performance curves.

Results: For matched low-dose modes, air kerma rates differed by 11.2% (System 1 Low Dose: 5.44 mGy/min; System 2 Low Dose: 6.05 mGy/min). For matched high-dose modes, air kerma rates differed by 7.0% (System 1 High Dose: 19.38 mGy/min; System 2 High Dose: 18.05 mGy/min). At these commensurate dose levels, both systems demonstrated comparable visibility of line-pair groups and high-contrast targets. However, contrast-detail analysis revealed atypical preservation of low-contrast object visibility on Fluoroscopy System 1 relative to Fluoroscopy System 2, with contrast-detail performance degrading less rapidly at lower contrast levels. This behavior is consistent with enhancement from proprietary image processing.

Conclusion: When operated at matched air kerma rates, the two fluoroscopy systems demonstrated comparable radiation dose output and spatial resolution performance. Differences in low-contrast detectability were primarily attributable to differences in image processing rather than exposure conditions. These results highlight the importance of considering algorithm-driven image appearance, in addition to dose metrics, when comparing fluoroscopy system performance.

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INTRODUCTION

Dedicated fluoroscopy systems from different manufacturers may employ fundamentally different approaches to radiation management, image acquisition, and proprietary image processing. As a result, two rooms performing similar clinical procedures may produce different image-quality characteristics and may be used differently by physicians, with potential consequences for fluoroscopy time and patient radiation exposure. Medical physicists can investigate these technology-dependent differences through controlled measure-ments that isolate radiation output from image-processing effects. This study describes a physicist-initiated comparison of two dedicated cardiac fluoroscopy systems designed to determine whether differences in low-contrast image quality at commensurate dose levels could have meaningful clinical and operational consequences.

METHODS AND MATERIALS

- **Phantom setup:** A Leeds TOR 18-FG fluoroscopy phantom was positioned between 18 cm of PMMA and imaged on two dedicated cardiac fluoroscopy systems: a Philips Allura system (**System 1**) with the Clarity dose-reduction upgrade and a GE Innova platform (**System 2**).
- **Dose matching:** Each system was evaluated in its respective clinical low- and high-dose fluoroscopy modes. Air kerma rate was measured at the FDA reference point to identify commensurate dose conditions for cross-system comparison.
- **Image acquisition:** Last-image-hold frames were acquired using standardized phantom geometry reproduced as closely as practicable between systems (**Figure 1**).
- **Subjective image-quality assessment:** Spatial resolution and high-contrast visibility were evaluated by recording visible line-pair groups and contrast-detail targets.
- **Objective image-quality assessment:**
  - Standardized regions of interest were placed within individual contrast discs and adjacent background regions to measure signal contrast and image noise.
  - Contrast-to-noise ratio (CNR) was calculated for each target and used to construct contrast-detail performance curves for each system and dose condition.

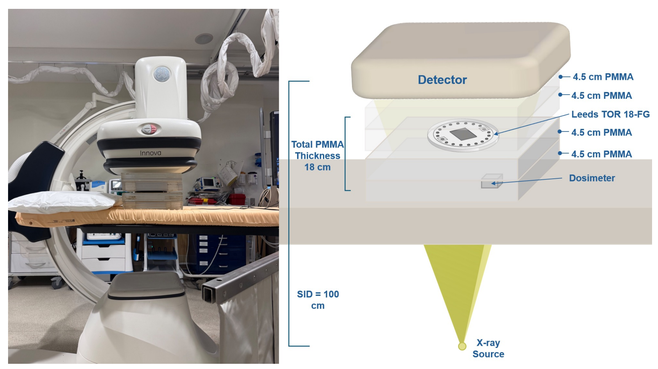

Figure 1: Experimental setup example photo of System 2 (left) and standardized phantom geometry design schema (right).

RESULTS

- **Dose matching:** Air kerma rates were closely matched between systems in both clinical fluoroscopy modes. Low-dose rates were **5.44 mGy/min** for System 1 and **6.05 mGy/min** for System 2, an **11.2% difference**. High-dose rates were **19.38 and 18.05 mGy/min**, respectively, a **7.0% difference** (**Table 1**).
- **High-contrast performance:** At commensurate dose levels, both systems demonstrated comparable spatial resolution and high-contrast target visibility.
- **Low-contrast performance:** System 2 showed progressive degradation in contrast-to-noise performance as target contrast decreased, consistent with classic noise-limited behavior in a system with a higher noise floor.
- **Preservation of low-contrast information:** System 1 demonstrated greater preservation of low-contrast target visibility across the contrast-detail range (**Chart 1**, **Figure 2**).
- **Interpretation:** Because radiation output was closely matched, the observed low-contrast performance differences were not explained by exposure conditions alone and were consistent with differences in proprietary image processing.

Table 1: Dose rate measurements for the two systems and low- and high-dose conditions tested corrected to the FDA reference point.

	System 1 Dose Rate (mGy/min)	System 2 Dose Rate (mGy/min)
Low-Dose	5.44	6.05
High-Dose	19.38	18.05

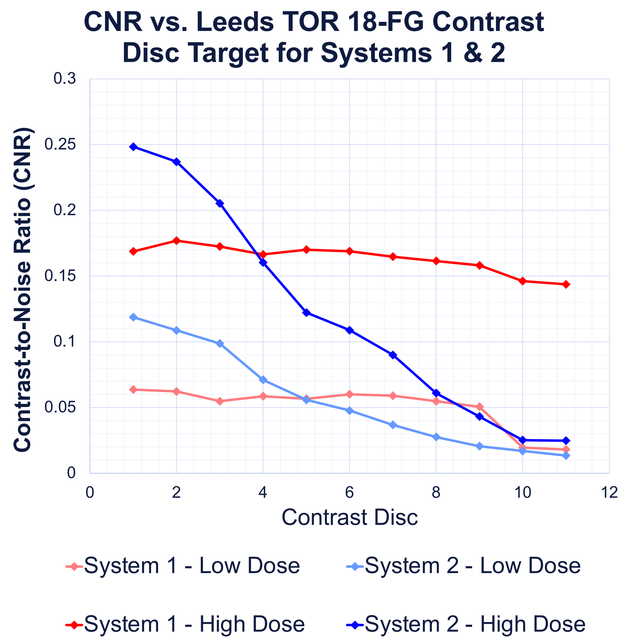

Chart 1: CNR measurements of targets in the Leeds TOR-FG Phantom for the two systems and two dose conditions tested.

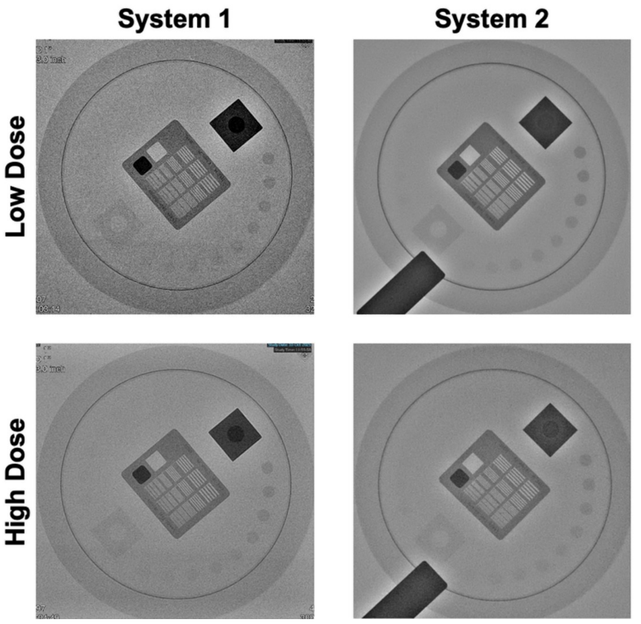

Figure 2: Leeds TOR-18 FG Phantom for the two systems and two dose conditions tested.

DISCUSSION

- At commensurate air kerma rates, both systems showed comparable spatial resolution and high-contrast visibility, but System 1 better preserved low-contrast information.
- LIH images include effects of vendor-specific image processing, reflecting what operators see during procedures. Differences in image processing algorithms can have a pronounced effect on both perceived and measured image quality, even at matched dose rate levels.
- Because the systems use different detector technologies and imaging chains, this was not a fully controlled detector comparison using metrics such as DQE, MTF, or NPS.
- Despite these limitations, the measured differences aligned with clinician-perceived performance differences between rooms and demonstrate the value of physicist-led comparative evaluation.

CONCLUSIONS

The two cardiac fluoroscopy systems demonstrated comparable radiation output and spatial resolution under commensurate dose conditions; however, System 1 showed substantially greater preservation of low-contrast information, consistent with the effects of proprietary image processing. These findings provided a plausible technical basis for observed differences in clinical utilization and cumulative air kerma, where system 2 was less preferred vs system 1, and was associated with higher CAK per procedure. The results were communicated to clinical and vendor stakeholders and informed the subsequent decision to replace System 2 with GE's latest-generation platform, demonstrating the direct operational impact of quantitative medical physics evaluation.