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Ranking of Mobile C-Arm Image Quality Using Contrast–Detail Detectability Metrics

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ABSTRACT

Objective quantitative methods for evaluating fluoroscopic image quality remain limited in clinical practice. We evaluated **11 mobile C-arm fluoroscopy systems** using a contrast-detail phantom and compared human observer performance with **Rose Signal-to-Noise Ratio (Rose-SNR)** analysis. The **flat-panel detector** demonstrated superior image quality. These findings support standardized contrast-detail methodology for fluoroscopic systems image quality study and highlight the need for improved objective image quality metrics.

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INTRODUCTION

Problem: Fluoroscopic image quality is routinely assessed in clinical practice, yet no standardized quantitative image quality metric exists.
Knowledge gap: Although contrast-detail methodology is widely used for radiographic quality control and image quality evaluation, no standard phantom or scoring protocol has been established for fluoroscopy.
Study objective: This study evaluates the feasibility of applying **contrast-detail methodology** to assess image quality in **mobile C-arm fluoroscopy systems** using both human observer assessment and **Rose Signal-to-Noise Ratio (Rose-SNR)**[1] analysis.

METHODS AND MATERIALS

Image acquisition: A contrast-detail phantom (Sun Nuclear Model 1151), containing disks with varying radii along the x-axis and varying depths along the y-axis, was placed on a **2.4 mm Cu sheet** and imaged on **11 mobile C-arm systems** (10 C-arms were image intensifier - based and one of them was flat panel detector - based) using a standardized geometry with automatic exposure control (AEC). Displayed air kerma rate (AKR) was recorded for each system. The phantom was held at 15 cm from the image intensifier.
Observer assessment: Images were reviewed on a medical-grade display (Vendor/Model: EIZO/RX660) using the default window and level settings. Disk visibility was first scored by **one observer** viewing the full phantom and then by **the same observer** using a mask to show only one target at a time while covering all of the other targets. We used 9 inch field of view.
Data analysis: Rose Signal-to-Noise Ratio (Rose-SNR) model was used to calculated SNR for each disk. Contrast-detail curves were generated and fitted using **f(r)=k/r+b**, and system rankings were compared using **Kendall's tau metric**[2].

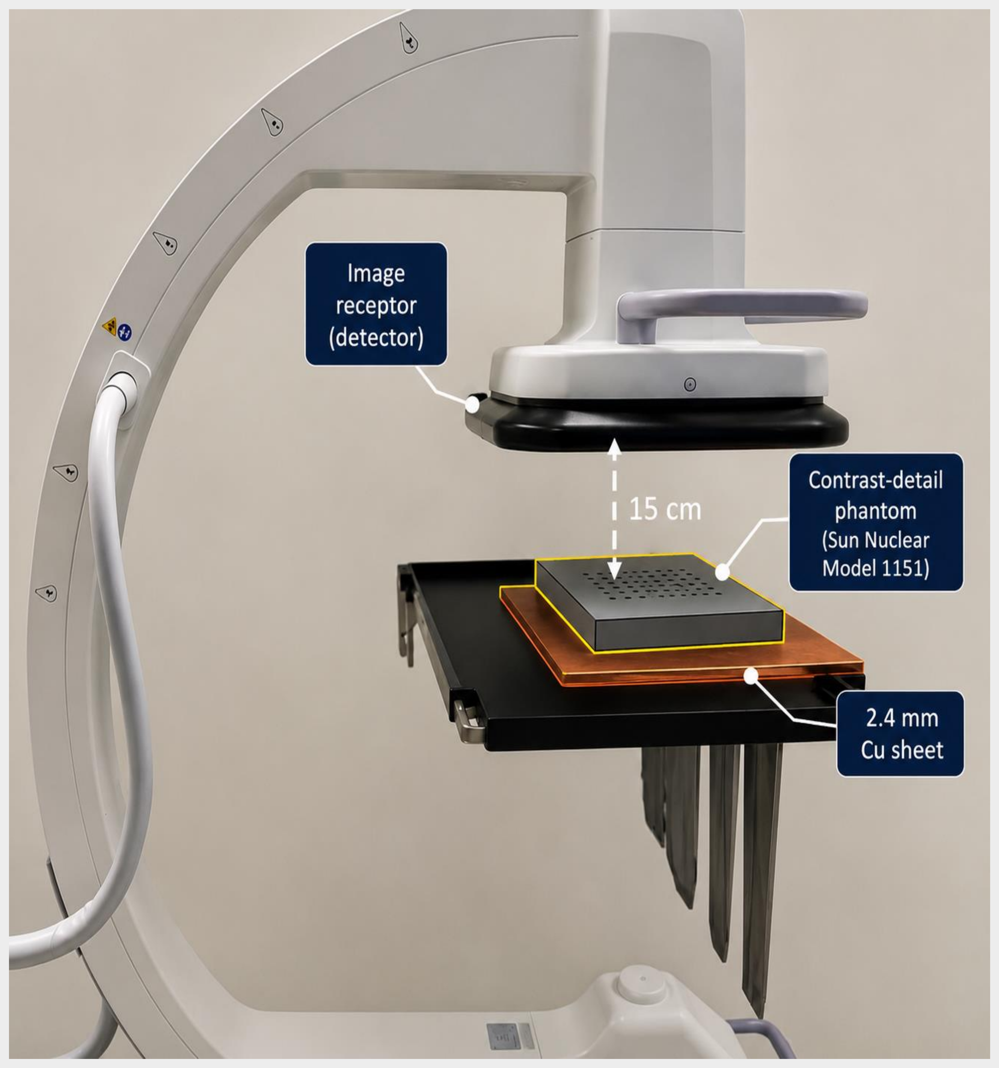

Figure 1. Experimental setup used for image acquisition. (SID: 100 cm; C-D phantom to Receptor: 15 cm.

RESULTS

- **The flat-panel C-arm** demonstrated the best image quality, exhibiting the lowest threshold contrast across all disk diameters **(Fig. 2).**
- Although the II-based systems had similar AKRs, their **contrast-detail performance** varied considerably **(Fig. 3).**
- Three target detection approaches were evaluated: (1) detection by a single observer, (2) detection by the same observer with a mask applied to isolate the target, and (3) detection predicted using the Rose signal-to-noise ratio (Rose-SNR) model. Mask-based observer scoring detected lower contrast thresholds than full-phantom viewing.
- Kendall's tau[2] correlation is used to study the correlation between all three methods for image quality assessment. **Human observer rankings** showed moderate agreement **(τ = 0.54, p = 0.047),** whereas **Rose-SNR** showed poor agreement **(Table 1).**

Scoring method	Count	κ (kappa)
Full vs. Mask	0.54, *p* = 0.047	0.18, *p* = 0.47
Full vs. Rose-SNR	−0.21, *p* = 0.41	0.11, *p* = 0.65
Mask vs. Rose-SNR	0.27, *p* = 0.31	0.00, *p* = 1.00

Table 1: Kendall's tau (τ) correlation and Cohen's kappa (κ) agreement between system rankings obtained using full-phantom observer scoring, mask-based observer scoring, and the Rose signal-to-noise ratio (Rose-SNR) model.

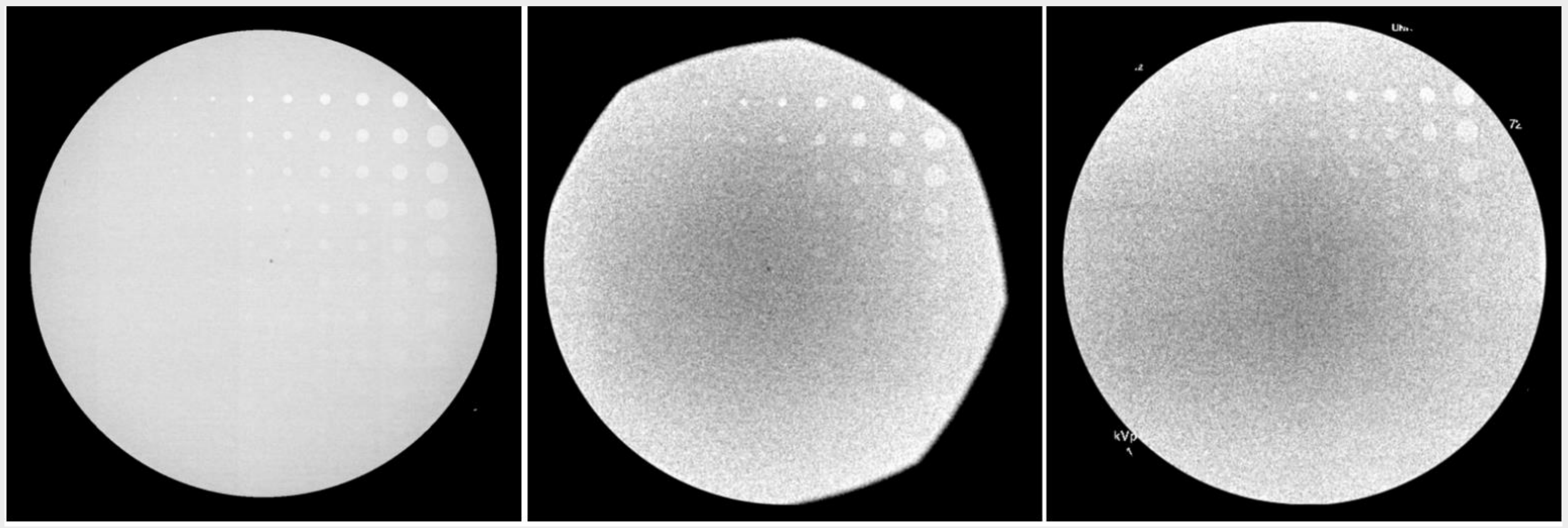

Figure 2. Representative contrast-detail phantom images acquired using a flat-panel C-arm (left), a high-performing II-based C-arm (center), and a lower-ranked II-based C-arm (right).

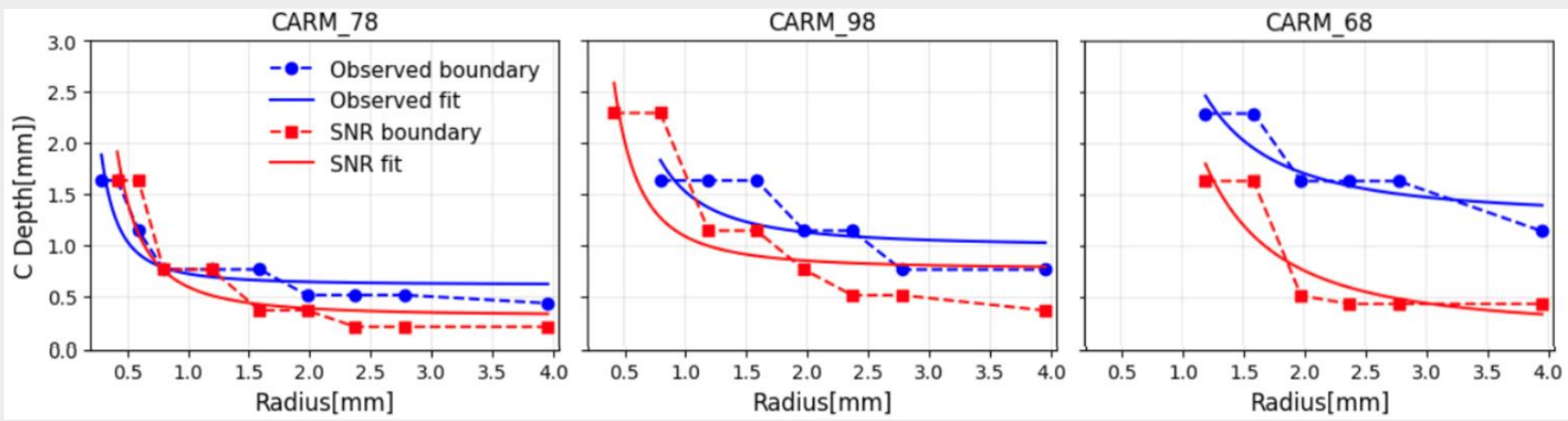

Figure 3. Contrast-detail curves for the three systems shown in Figure 2. Blue symbols represent human mask based observer scores and red symbols represent Rose-SNR values. Lower curves indicate superior image quality.

DISCUSSION

Eleven mobile C-arm systems were evaluated, including **one flat-panel detector system** (4 years old) and **ten image-intensifier (II)-based systems** (7–14 years old). All systems were assessed under identical imaging conditions using a contrast-detail phantom, fixed geometry, and automatic exposure control (AEC). Image quality was evaluated using **three complementary scoring methods** analysis. This standardized study design enabled a direct comparison of detector technologies while minimizing differences attributable to acquisition conditions.

CONCLUSIONS

Contrast-detail detectability is commonly used to assess radiographic image quality. Our study highlights the importance of controlling human observation conditions to reduce variability and the need for developing a numerical model to minimize subjectivity in human assessments.

REFERENCES

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2. Kendall MG. A new measure of rank correlation. *Biometrika*. 1938;30(1-2):81-93. doi:10.1093/biomet/30.1-2.81