A Comparative Study of Image Quality between Computed Radiography and Digital Radiography Systems

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Abstract- **Aim of the Study: The abstract starts by clearly stating the aim of the study, which is to compare the image quality between two types of radiography systems: Computed Radiography (CR) and Digital Radiography (DR). The focus is on four key parameters: spatial resolution, contrast, noise, and image sharpness. These are the primary factors that determine how clear and useful a radiographic image is for diagnostic purposes.**

Method and material: Quantitative image analysis: This uses digital software tools to measure the performance of the systems in terms of the parameters of interest (spatial resolution, contrast, noise, sharpness). For instance, spatial resolution could be measured using pixel-based analysis, while noise might be quantified using statistical measures. Qualitative visual evaluation: This involves radiologists subjectively evaluating the images to provide insights into how usable and clear the images are for clinical decision-making. Their input helps to add a human element to the findings, considering that technology alone doesn't always capture all nuances in clinical practice. The study used standardized phantoms—special objects designed to mimic human anatomy.

Results: The study's results clearly favor DR in terms of image quality: Higher spatial resolution (up to 5 lp/mm) in DR compared to CR, meaning DR can capture finer details in images. Enhanced contrast detection, especially in situations where the contrast between structures is low (for example, differentiating soft tissues with similar density). Lower noise levels, particularly when using low-dose settings. Lower noise improves the clarity of the image, making it easier to see smaller structures and abnormalities. Sharper image details, meaning the edges of structures are more defined and precise in DR images, which aids in diagnostics, especially for identifying fractures or small lesions. These findings suggest that DR systems have superior image quality, making them the preferred choice for modern clinical settings.

Conclusion: The study concludes that the superior image quality of DR supports its adoption in modern radiology practices. This aligns with the growing trend of adopting more advanced imaging systems that offer better performance and improved patient outcomes.

Keywords- **Computed Radiography, Digital Radiography, Spatial Resolution, Contrast, Image Noise, Sharpness, Image Quality.**

I. INTRODUCTION

Radiographic imaging has evolved considerably from its origins in analog film systems to the adoption of advanced digital imaging technologies. This transformation has been driven by the increasing demand for more efficient workflows, faster image processing, improved diagnostic accuracy, and integration into broader healthcare information systems. In the realm of digital imaging, Computed Radiography (CR) and Digital Radiography (DR) are the two most prominent modalities currently in widespread clinical use.

Computed Radiography (CR) serves as an intermediary technology between the traditional film-screen systems and modern digital workflows. CR utilizes photostimulable phosphor plates housed within cassettes, which capture the latent x-ray image. This latent image is then read by a laser scanning device that stimulates the phosphors, causing them to emit light, which is then converted into an electrical signal to produce a digital image. Although CR systems improve over analog methods in terms of flexibility and digital storage, they still involve multiple processing steps that can introduce image degradation and noise.

In contrast, Digital Radiography (DR) employs flat-panel detectors or charge-coupled devices (CCDs) that directly capture the image in a digital format at the point of exposure. This technology enables near-instantaneous image acquisition and display, improving workflow efficiency and supporting real-time decision-making. Additionally, DR systems are fully compatible with Picture Archiving and Communication Systems (PACS), allowing for seamless image retrieval, sharing, and long-term archiving.

The move to DR has marked a significant step forward in image quality and operational efficiency. However, both CR and DR have distinct technical characteristics that impact image performance, including differences in spatial resolution, contrast sensitivity, noise levels, and image sharpness. Understanding these differences is crucial for healthcare institutions aiming to make informed decisions about imaging equipment acquisition and clinical application.

This study undertakes a systematic comparison of image quality between CR and DR systems, focusing on four critical parameters: spatial resolution, contrast, noise, and image sharpness. By employing standardized imaging phantoms and consistent exposure conditions, the research aims to provide both objective measurements and subjective evaluations to support evidence-based choices in radiographic imaging technologies.

The transition to digital radiography has significantly influenced image quality, workflow efficiency, and patient management. However, each modality presents distinct technical characteristics that influence image performance. CR, although cost-effective and suitable for retrofitting existing film-based systems, often exhibits limitations in spatial resolution and noise suppression due to intermediate processing steps. DR, with its direct digital acquisition, is reputed for higher resolution, reduced image noise, and superior contrast.

This study is designed to systematically compare the image quality of CR and DR based on four essential parameters: spatial resolution, contrast, image noise, and sharpness. By using standardized phantoms and consistent imaging conditions, the research aims to provide objective and subjective data to guide radiology departments in selecting optimal imaging systems.

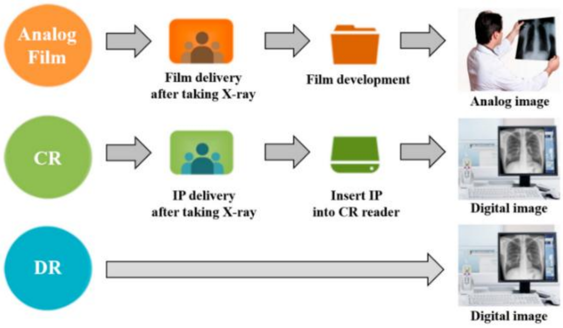


Fig: Show process difference between Computed and Digital Radiography.

II. OBJECTIVES

- To assess and compare spatial resolution in CR and DR systems by utilizing line pair phantoms under standardized exposure parameters. This objective includes evaluating the ability of each modality to resolve fine image details, quantified in line pairs per millimeter (lp/mm), and identifying the threshold at which structures become indistinguishable. Both objective measurements and subjective assessments will be employed to determine clinical significance.
- To evaluate contrast capabilities of both systems.
- To measure image noise levels across both modalities.
- To analyze and compare image sharpness.

III. MATERIALS AND METHODS

This section outlines the methodology employed to compare CR and DR systems. The study was conducted in a controlled radiology department environment to ensure consistency across tests. All equipment was calibrated according to manufacturer specifications prior to data collection. A series of standardized tests were conducted using phantoms designed to evaluate spatial resolution, contrast sensitivity, noise levels, and edge sharpness. Each test was repeated three times for each modality to ensure repeatability and statistical significance.
All images were stored in DICOM format and evaluated using image processing software with capabilities for pixel value analysis, modulation transfer function (MTF) calculation, and noise quantification. Radiologists involved in subjective evaluation were blinded to the modality to avoid bias. A 5-point Likert scale was used to assess perceived image quality, anatomical detail visibility, and overall diagnostic acceptability.

The following subsections describe the specific tools, imaging parameters, and evaluation methods used in greater detail.

3.1 Equipment Used:

In this comparative study, the following radiographic systems were employed, each calibrated and maintained in accordance with manufacturer guidelines to ensure optimal performance and consistency in data acquisition:

- Computed Radiography (CR) System: The CR unit used was the Fuji FCR Prima T2 Model, which utilizes photostimulable phosphor (PSP) imaging plates housed in cassettes. These plates store the latent image after x-ray exposure and are processed through a laser scanner that stimulates the plate to emit light. The emitted light is then converted into an electronic signal and digitized for image formation. The CR reader system was configured with default clinical processing parameters and subjected to daily quality assurance checks.
- Digital Radiography (DR) System: The DR unit employed was the Agfa DR 600 Model equipped with a flat-panel detector (FPD) made of amorphous silicon with a cesium iodide (CsI) scintillator. The DR system performs direct digital image acquisition, eliminating the need for intermediary steps. Images were captured and transmitted in real time to a PACS-integrated workstation. The DR system features advanced noise reduction algorithms, automatic exposure control (AEC), and high DQE (Detective Quantum Efficiency) characteristics, which significantly impact image quality.

Additional imaging equipment included:

- High-frequency x-ray generator compatible with both systems.
- Standard radiographic table and Bucky stand.
- Radiation dosimeter to monitor exposure levels during each scan.

All equipment underwent cross-calibration to ensure exposure consistency across modalities during phantom-based image acquisition. CR system: Fuji FCR Prima T2 Model, Photostimulable phosphor plates.

- DR system: Agfa DR 600 Model Flat Panel Detector.

3.2 Phantom and Test Tools:

- Line pair phantoms for spatial resolution.
- Step wedge phantom for contrast assessment.
- Uniformity phantoms for noise analysis.
- Edge device phantoms for sharpness evaluation.

3.3 Image Acquisition Parameters:

- Standardized exposure conditions (kVp, mAs, SID).
- Same anatomical region simulated in all tests.

3.4 Image Quality Assessment:

- Objective measurements using software analysis (DICOM tools).
- Subjective evaluation by three experienced radiologists using Likert scale.

IV. RESULTS

The findings of this study are presented in four major categories based on the key image quality parameters assessed: spatial resolution, contrast, noise, and sharpness. Data was gathered through both objective software-based analyses and subjective evaluations by radiologists using a Likert scale. Quantitative metrics were expressed in line pairs per millimeter (lp/mm), contrast-to-noise ratio (CNR), standard deviation of pixel values for noise, and edge gradient measurements for sharpness. Qualitative data included radiologist ratings based on clarity, diagnostic acceptability, and visibility of anatomical details. Each parameter is discussed in detail below.

4.1 Spatial Resolution: Spatial resolution refers to an imaging system's ability to distinguish small objects that are close together and is usually quantified in terms of line pairs per millimeter (lp/mm). In this study, line pair phantoms were used to assess the ability of CR and DR systems to resolve fine detail. The Digital Radiography (DR) system consistently demonstrated superior performance, achieving spatial resolution up to 5 lp/mm. This indicates a higher capacity for resolving small anatomical structures, making it particularly useful for applications requiring fine detail, such as imaging of bone trabeculae or micro calcifications. In contrast, the Computed Radiography (CR) system could resolve only up to 3.5 lp/mm, reflecting its lower resolution capability. This limitation is attributed to the inherent characteristics of the phosphor plate technology used in CR and the intermediate step of laser scanning, which can introduce slight image degradation. Both objective software analysis and subjective evaluations by radiologists confirmed this distinction, with DR images rated higher in terms of clarity and structural detail visibility.

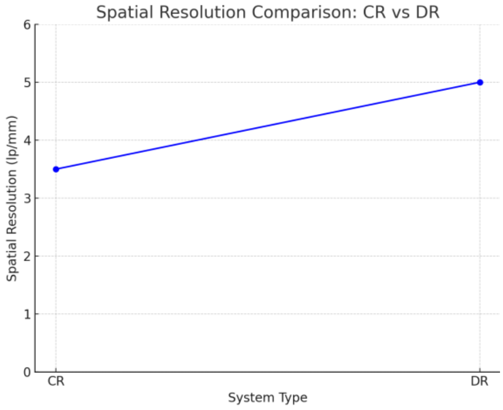


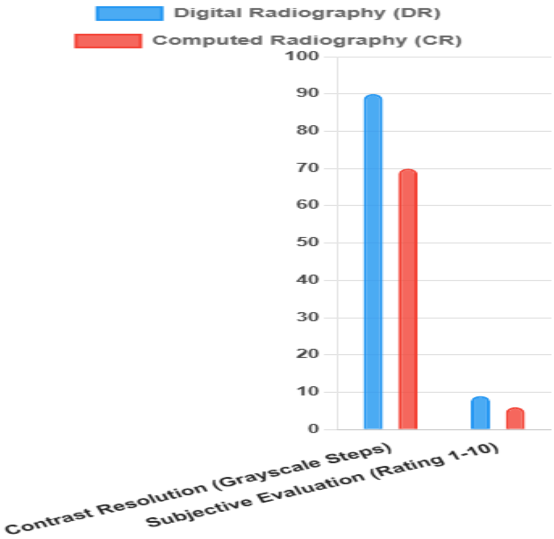
Fig: Spatial Resolution (lp/mm) Comparison

4.2 Contrast: Contrast refers to the ability of an imaging system to distinguish differences in the intensity of adjacent structures, which is essential for detecting subtle lesions and anatomical variations. In this study, contrast evaluation was performed using a step wedge phantom composed of multiple layers with incremental density variations. The DR system demonstrated a distinct advantage in contrast performance, particularly in its ability to differentiate low-contrast objects that are critical for early pathology detection.

The step wedge images produced by the DR system displayed a greater number of distinguishable grayscale steps compared to CR, indicating superior contrast resolution. This enhancement in DR is primarily attributed to its direct digital signal acquisition and higher dynamic range, allowing finer gradations in pixel intensity to be captured and displayed. In contrast, the CR system, with its analog-to-digital conversion process via phosphor plate scanning, exhibited limited dynamic range and some degree of signal loss, which diminished its ability to accurately represent subtle contrast differences.

Subjective evaluations by radiologists also confirmed this finding, with DR images consistently rated higher on the contrast visibility scale. These ratings were particularly pronounced in simulated soft tissue imaging conditions, where contrast sensitivity plays a crucial role in differentiating structures of similar density. Overall, the contrast superiority of DR contributes significantly to its diagnostic value in clinical settings.

Chart: contrast performance of Digital Radiography (DR) and Computed Radiography (CR)



4.3 Image Noise: Image noise refers to the random variation of pixel values in a digital image, often perceived as graininess, which can obscure fine anatomical details and reduce diagnostic confidence. In this study, noise was quantified using the standard deviation of pixel values within uniform regions of interest (ROIs) on phantom images.

Digital Radiography (DR) systems demonstrated significantly lower image noise compared to Computed Radiography (CR), especially under low-dose exposure settings. This reduction in noise is primarily due to the direct digital capture and advanced noise-reduction algorithms employed in DR systems. The flat-panel detectors used in DR are inherently more sensitive and efficient in x-ray photon detection, enabling clearer images with fewer quantum artifacts.

In contrast, CR systems exhibited higher noise levels, particularly in lower exposure images. This is attributed to multiple intermediate processing steps, including photostimulable phosphor plate scanning and analog-to-digital conversion, which can introduce signal degradation and increase noise.

Subjective assessments by radiologists aligned with the objective findings, consistently rating DR images as clearer and more diagnostically acceptable. Overall, the lower noise levels in DR enhance the clarity of anatomical structures and contribute to more reliable diagnostic interpretation, especially in pediatric or dose-sensitive imaging scenarios.

4.4 Image Sharpness: Image sharpness refers to the clarity of edges and the ability of an imaging system to depict the fine structural margins of anatomical features. Sharpness is critical for accurate diagnosis, especially in imaging areas such as skeletal structures, lung fields, and small soft tissue masses where precise edge definition is essential.

In this study, edge analysis was conducted using edge phantoms and gradient measurements to compare the sharpness between Computed Radiography (CR) and Digital Radiography (DR). The DR system exhibited significantly sharper image boundaries, which translated into clearer visualization of bone edges, vascular margins, and organ outlines. This was quantitatively measured through edge spread function (ESF) and modulation transfer function (MTF) calculations, which revealed steeper gradients and higher spatial frequency retention in DR images.

The superior performance of DR in image sharpness is attributed to the elimination of intermediate processing steps and the use of high-resolution flat panel detectors. These detectors reduce geometric blurring and maintain edge integrity from exposure to image reconstruction. Conversely, CR systems, which involve scanning phosphor plates with lasers, introduce some degree of mechanical and optical blur, thereby compromising edge fidelity.

Subjective analysis by radiologists also supported these findings. DR images were consistently scored higher for anatomical delineation and edge visibility, particularly in extremity and chest phantom evaluations. The ability of DR to produce sharper images enhances diagnostic accuracy by enabling better identification of subtle pathologies, such as hairline fractures, small nodules, or early-stage lesions.

V. DISCUSSION

The results of this comparative study highlight the notable superiority of Digital Radiography (DR) systems in delivering higher diagnostic image quality compared to Computed Radiography (CR). DR exhibited enhanced spatial resolution, which translates into improved visualization of fine anatomical structures such as trabecular bone, micro fractures, and small pulmonary nodules. This capability is particularly significant in high-detail imaging applications like orthopaedic and thoracic radiology.

DR also demonstrated superior image sharpness due to its direct digital capture and high-resolution detector arrays. This sharpness facilitates precise edge delineation, enabling radiologists to detect subtle changes in tissue morphology. The edge integrity of DR images provides clinicians with greater confidence in differentiating normal anatomy from early pathological alterations.

In terms of contrast, DR systems displayed a broader dynamic range and finer grayscale differentiation. This allowed for better separation of tissues with similar densities, crucial in soft tissue evaluations such as breast, abdominal, and cardiovascular imaging. DR's ability to accurately represent low-contrast differences contributes to earlier detection of lesions and more reliable interpretations.

Image noise, which can obscure anatomical detail and reduce diagnostic accuracy, was significantly lower in DR. The direct acquisition and sophisticated noise-reduction technologies used in DR reduce graininess and maintain clarity, even at lower radiation doses. This makes DR especially beneficial in pediatric imaging and for patients requiring repeated exposures, where dose minimization is essential.

Although CR systems remain relevant in certain clinical settings due to their affordability and compatibility with existing film-based infrastructure, their inherent limitations—such as lower resolution, greater noise levels, and reduced contrast performance—restrict their diagnostic utility in comparison to DR. Therefore, while CR may serve as a transitional solution, the adoption of DR aligns better with modern diagnostic requirements, offering improved efficiency, better patient outcomes, and long-term cost-effectiveness.

VI. CONCLUSION

This comparative analysis clearly establishes that Digital Radiography (DR) systems significantly outperform Computed Radiography (CR) systems across all key metrics of image quality—spatial resolution, contrast, noise reduction, and image sharpness. DR systems provide higher spatial resolution, enabling better visualization of fine anatomical structures such as bone trabecular and micro calcifications. They also offer superior contrast sensitivity, which is vital for detecting subtle soft tissue differences and early-stage pathologies. Additionally, DR systems exhibit markedly lower image noise, especially under low-dose exposures, making them particularly suitable for pediatric and dose-sensitive imaging applications. The sharpness of DR images, due to advanced detector technology and the absence of intermediate processing steps, leads to improved edge definition and overall diagnostic clarity.

From an operational standpoint, DR enhances workflow efficiency, reduces turnaround time, and integrates seamlessly with modern PACS environments, further justifying its adoption. While CR may still hold value in cost-sensitive or transitional settings, its limitations in image fidelity and processing speed are evident. Therefore, for institutions aiming to elevate diagnostic accuracy and optimize imaging services, transitioning to DR systems is not only beneficial but essential in the context of modern radiological practice.

REFERENCES

[1] Andriole KP. Productivity and cost assessment of filmless versus film-based radiology. Radiology. 2002;225(2):345-352.

[2] Reiner BI, Siegel EL. Radiology reporting: returning to our image-centric roots. AJR Am J Roentgenol. 2006;187(5):1151-1155.

[3] Ranschaert ER, et al. Radiology in the digital age: present and future. Insights Imaging. 2016;7(6):559-576.

[4] Bahar Mansoori, Karen K. Erhard, Jeffrey L. Sunshine. PACS Implementation and Benefits in Health Systems. Academic Radiology. 2012;19(2):229-233.

[5] Don MacDonald, Doreen Neville. Evaluating PACS Implementation—a Cost Benefit Analysis. J Digit Imaging. 2010;23(6):721-731.

[6] Honeyman-Buck J. PACS adoption. Semin Roentgenol. 2003;38(3):256-263.

[7] Dreyer KJ, Hirschorn DS, Thrall JH, et al. PACS: a guide to the digital revolution. Springer-Verlag; 2006.

[8] Rehani MM. Environmental impact of radiology: Need for awareness and action. Radiat Prot Dosimetry. 2011;147(1-2):169-172.

[9] Willaert R, et al. Evaluation of PACS in a clinical environment. J Digit Imaging. 2006;19(1):13-21.

[10] Seibert JA. Digital radiography: the bottom line comparison of CR and DR. Pediatr Radiol. 2004;34(9):567-578.

[11] Fauber TL. Radiographic Imaging and Exposure. 5th ed. Elsevier; 2020.

[12] Parizel PM, et al. Digital radiography: Room design and workflow. Eur Radiol. 2006;16(7):1621-1628.

[13] Geijer H, et al. Image quality and radiation dose in thoracic digital radiography. Radiat Prot Dosimetry. 2009;136(2):105-110.

[14] Moore CS, Liney GP, Beavis AW, et al. Diagnostic efficacy of CR and DR systems. Br J Radiol. 2010;83(995):104-109.

[15] Bushberg JT, et al. The Essential Physics of Medical Imaging. 3rd ed. Lippincott Williams & Wilkins; 2012.

[16] Seeram E. Digital Radiography: An Introduction. Delmar Cengage Learning; 2010.

[17] Zhou X, et al. Advances in Digital Radiography. Quant Imaging Med Surg. 2015;5(5):767-771.

[18] Langer SG. Information systems in radiology: PACS evolution. J Am Coll Radiol. 2008;5(12):987-993.

[19] Martin CJ. Environmental effects of radiographic imaging. Radiat Prot Dosimetry. 2011;147(1-2):165-168.

[20] Daffner RH. Imaging in emergency radiology: CR vs DR. Radiology Clinics. 2006;44(2):257-272.

[21] Iball GR, Brettle DS. Radiation dose implications of PACS and DR transition. Br J Radiol. 2009;82(978):1035-1040.

[22] Geijer H, et al. Clinical image quality comparison between CR and DR. Eur Radiol. 2001;11(9):1784-1790.

[23] Mahesh M. Digital radiography: Relative advantages and radiation doses. Radiol Clin North Am. 2009;47(1):109-124.

[24] Brady A, Laoide RO, McCarthy P, et al. Discrepancy and Error in Radiology: Concepts, Causes, and Solutions. Am J Roentgenol. 2012;199(4):741-745.

[25] Giger ML. Digital Imaging in Radiology: A Look to the Future. Radiology. 2006;241(2):353-360.