World Journal of Biology Pharmacy and Health Sciences
eISSN: 2582-5542
Cross Ref DOI: 10.30574/wjbphs
Journal homepage: https://wjbphs.com/

(RESEARCH ARTICLE)

Check for updates

Revolutionizing critical care radiography: A cost-effective retrofitted digital radiography solution

Nivedita Radder [1,*], Avinash Nanivadekar [1] and Shrinivas Radder [2]

[1] *Department of Radiology- Ruby Hall Clinic, Pune-India*.*
[2] *Department of Radiology- RIMS, Ranchi, India.*

World Journal of Biology Pharmacy and Health Sciences, 2025, 21(02), 555-564

Publication history: Received on 12 January 2025; revised on 15 February 2025; accepted on 18 February 2025

Article DOI: https://doi.org/10.30574/wjbphs.2025.21.2.0221

Abstract

Background: Portable radiography is essential in critical care management, but traditional computed radiography (CR) systems in the Indian subcontinent face significant delays in image processing, hindering timely interventions. This study evaluates a cost-effective solution: retrofitting portable X-ray units with digital radiography (DR) capabilities.

Objectives: To compare the diagnostic performance, turnaround time, workflow efficiency, and clinical impact of retrofitted DR systems versus conventional CR in critical care settings.

Methods: A comparative study was conducted at Ruby Hall Clinic, Pune, India, from July to September 2016. We analyzed 1,000 portable chest X-ray examinations (500 CR, 500 DR) performed by two experienced radiographers. Key performance indicators included preparation, imaging upload, and treatment response time. Statistical analysis was performed using unpaired t-tests with significance set at $p < 0.05$.

Results: The retrofitted DR system demonstrated significant improvements across all metrics. Examination duration decreased from 51.02 minutes (CR) to 15.2 minutes (DR). Preparation time was reduced from 9.9 to 6.8 minutes, and post-acquisition processing time from 25.3 to 4 minutes ($p < 0.0001$). Treatment response time improved from 14.7 to 3 minutes. Overall workflow productivity increased by 96%. Additional benefits included reduced radiation exposure, decreased retake need, and substantial cost savings through reduced film usage and optimized resource utilization.

Conclusion: Retrofitting existing radiography systems with DR capabilities presents a viable, cost-effective solution for improving critical care imaging in resource-constrained settings. This approach significantly enhances workflow efficiency, reduces treatment response time, and improves patient outcomes while maintaining image quality and safety standards. The successful implementation of this technology could revolutionize critical care imaging practices in developing regions.

Keywords: Digital Radiography; Critical Care; Retrofitted Systems; Workflow Efficiency; Cost-Effectiveness; Portable X-Ray; Healthcare Innovation

1. Introduction

Portable radiography is necessary to manage critically ill patients, mainly Indian subcontinent, which primarily depends on analog or computed radiography units for imaging. However, they have one significant shortcoming — developing an image after radiation exposure can take days because there's no on-site processing. Consequently, the 24–48 hour

* Corresponding author: Nivedita Radder.

delay with traditional measurement methods prevents timely interventions from being made in critical care units. It frequently results in unnecessary laboratory investigations and prolonged ICU stays [1, 2].

Here, we describe a novel approach that may enable the widespread use of this methodology: retrofitting digital radiography systems to older portable units. It overcomes the financial constraints of implementing a complete DR system; thus, it can be suitable for such hospitals in developing countries.

1.1. The Need for Immediate Imaging in Critical Care

In severe cardiorespiratory conditions, chest x-rays are obtained daily in ICU to monitor these patients and assist evaluation: airway devices such as endotracheal tubes (ETT) or central line placements and recognition of complications including pneumothorax remain an important diagnostic feature. A timely grasp of these troubles via prompt hiatal image availability is significant for fast intervention and enhances patient outcomes [3, 4]. [Fig 1]

1.2. Advantages of Digital Radiography in Critical Care

Digital radiography provides the following advantages compared to traditional techniques;

- Faster Image Availability: DR systems deliver images within seconds, allowing rapid image review by physicians, resulting in faster decision-making and potentially leading to lowering ICU length of stay and reducing unnecessary lab tests [5] .
- Better Image Quality: DR offers superior image quality with a lower retake need, leading to more accurate diagnoses and less radiation exposure [6].
- Improved Workflow: With Picture Archiving and Communication Systems, digital image storage allows immediate access to images all through the enterprise, providing faster communication between Radiologists, referring physicians, or other healthcare providers and opening up new doors for collaboration [7].

Study Objectives

This study aims to investigate quantitatively the influence of our experience on the implementation of a retrofitted DR system for portable radiography examination used during ICU. Our specific objectives were:

Our specific objectives were:

- Compare and evaluate the diagnostic performance of digital and computed radiography in critical care units.
- Compare the turnaround time for treatment planning decisions based on image acquisition using CR and DR.
- Compare the efficiency and workflow enhancement of portable radiographs using CR versus DR.
- Evaluate the impact on clinical outcomes in clinical emergency portable radiographs using DR.

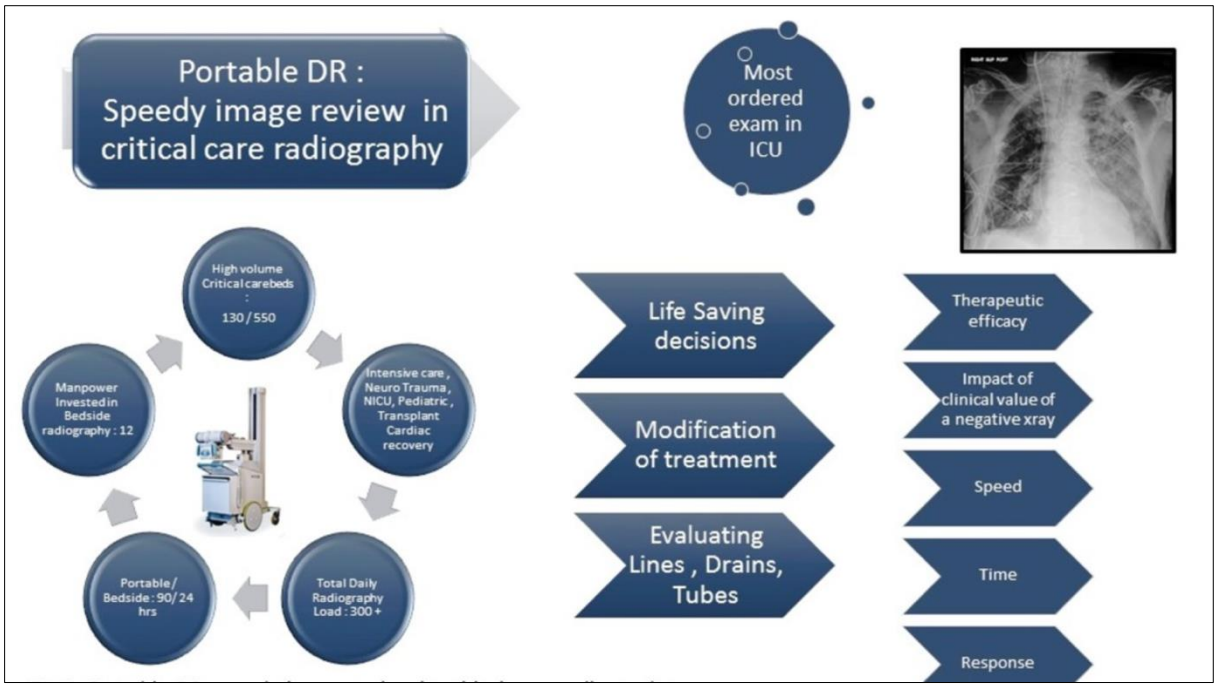

Figure 1 Portable DR, speedy image review in critical care Radiography

2. Materials and Methods

2.1. Equipment

This study utilized the following equipment:

- Retrofitted DR System: MobileArt Eco DR SHIMADZU with a retrofitted DR detector, a computer tablet with Wi-Fi capabilities, and integration with Nova PACS version 8.0.11.15. [Fig 2]
- CR System: MobileArt Eco X-Ray SHIMADZU with CR cassettes, a direct view cassette reader, and integration with Nova PACS version 8.0.11.15.

2.2. Study Design and Data Collection

We conducted a comparative study in two high-volume critical care units at Ruby Hall Clinic, Pune, India, from July 2016 to September 2016. A total of 1000 portable chest X-ray examinations (500 using CR and 500 using the retrofitted DR system) were performed on critically ill patients.

To minimize inter-operator variability, only two experienced radiographers with extensive experience in critical care portable radiography were involved in data collection. Both radiographers received comprehensive training on operating the retrofitted DR system before the study commenced [8] .

2.3. Data Analysis

We measured the following key performance indicators for both CR and DR systems:

- Preparation Time: Time taken from the start of the examination to image availability on PACS.
- Imaging Upload Time: Time taken for images to become visible to clinicians on PACS.
- Treatment Response Time: Time elapsed between image visualization and any subsequent change in treatment strategy.

The mean time intervals for each indicator were compared between the DR and CR systems using an unpaired t-test assuming unequal variance. Statistical significance was set at $p < 0.05$. We used Microsoft Excel Data Analyzer 2007 for all statistical analyses.

Note: As the primary focus of this study was to evaluate the performance of the imaging systems themselves, no patient-specific data were collected.

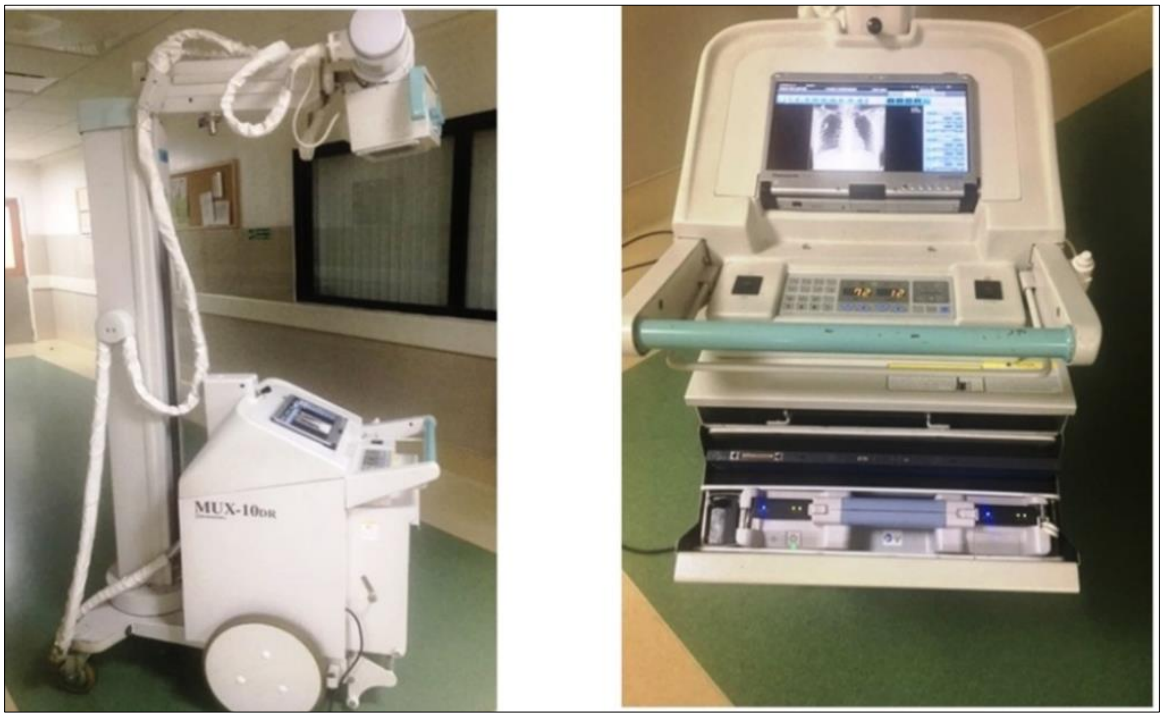

Figure 2 The retrofitted wireless network-based digital portable radiography system. (Courtesy-onsite portable DR, Ruby Hall clinic, India

3. Results

Our data reveal that the retrofitted DR system has distinct clinical, organizational, and financial implications in terms of workflow productivity effectiveness (WPE), patient safety outcomes (PSO), quality of care results (QOC), and cost-effectiveness efficiency (CEE). [Fig 3]

3.1. Workflow Productivity Enhancement

The DR system dramatically enhanced workflow productivity, achieving a **96%** increase compared to the CR system [9] . [Fig 4]This improvement stemmed from significant time reductions across various stages of the imaging process:

- **Examination Duration:** The DR system facilitated significantly faster examinations ($p < 0.0001$), with a mean duration of **15.2 minutes** compared to **51.02 minutes** for CR.
- **Preparation Time:** Preparation time, defined as the time from examination start to image availability on the Picture Archiving and Communication System, was significantly shorter ($p < 0.0001$) with DR (**6.8 minutes**) compared to CR (**9.9 minutes**).
- **Post-Acquisition Processing Time:** The time required for post-acquisition processing and image availability on PACS was significantly reduced ($p < 0.0001$) with DR (**4 minutes**) compared to CR (**25.3 minutes**).

3.2. Treatment Response Time

The DR system also led to a faster treatment response time, averaging **3 minutes** compared to **14.7 minutes** with CR. This expedited decision-making process is crucial in critical care settings where timely interventions can significantly impact patient outcomes.

3.3. Additional Benefits

While not quantitatively analyzed in this study, our observations suggest that the DR system offers substantial benefits in patient safety and clinical outcomes:

- **Patient Safety:** The DR system's potential to reduce radiation exposure through optimized imaging protocols and reduced retake rates contributes to enhanced patient safety.
- **Clinical Outcomes:** Faster image availability and improved image quality with DR can lead to more accurate diagnoses, timely interventions, and potentially improved clinical outcomes.

3.4. Cost Savings and Workflow Changes

The transition to a DR-based workflow resulted in notable cost savings and workflow improvements:

- **Reduced Film Utilization:** Eliminating the need for physical films translates into significant cost reductions associated with film purchasing, processing, and storage.
- **Optimized Manpower Allocation:** The streamlined workflow with DR allows for more efficient allocation of staff time, potentially reducing labor costs.
- **Reduced Equipment Costs:** The DR system minimizes expenses related to CR cassette maintenance and laser printer usage.

Furthermore, the integration of PACS and mobile applications for image review enhances accessibility and collaboration among healthcare providers, further optimizing workflow efficiency [10] . [Fig 5]

3.5. Clinical Benefits

Although a detailed analysis of clinical benefits fell outside the scope of this study, the shift from CR to DR in the ICU setting demonstrably improved patient safety [11] . This improvement is primarily attributed to the DR system's ability to:

- **Reduce Radiation Dose:** DR technology allows for lower radiation doses compared to CR, minimizing patient exposure to potentially harmful radiation.
- **Minimize Retakes:** The superior image quality and digital manipulation capabilities of DR significantly reduce the need for repeat examinations, further reducing radiation exposure.

These factors collectively contribute to a safer imaging environment for critically ill patients.

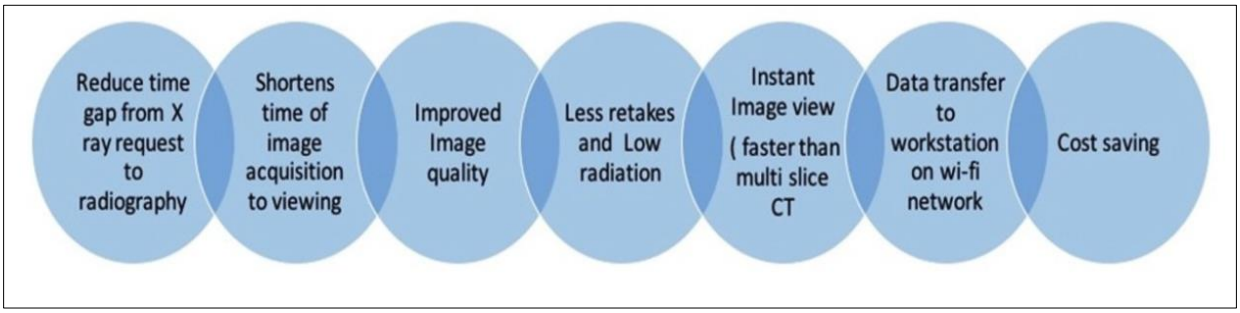

Figure 3 Improved Productivity by retrofit DR

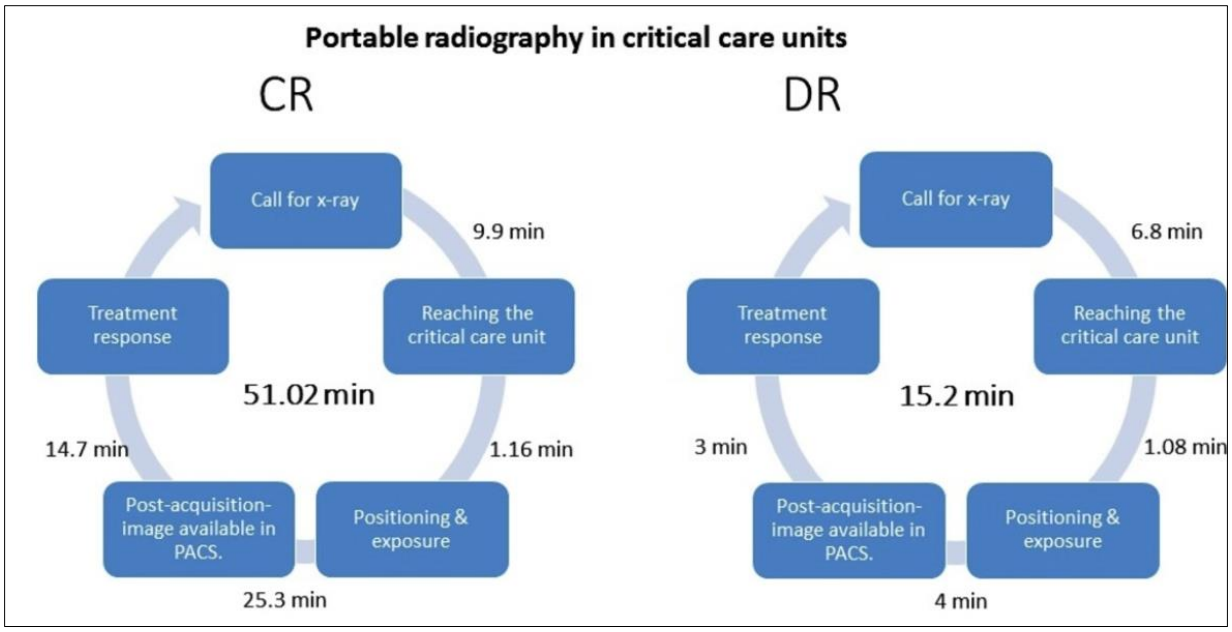

Figure 4 Statical analysis in terms of mean time taken for each procedural step.

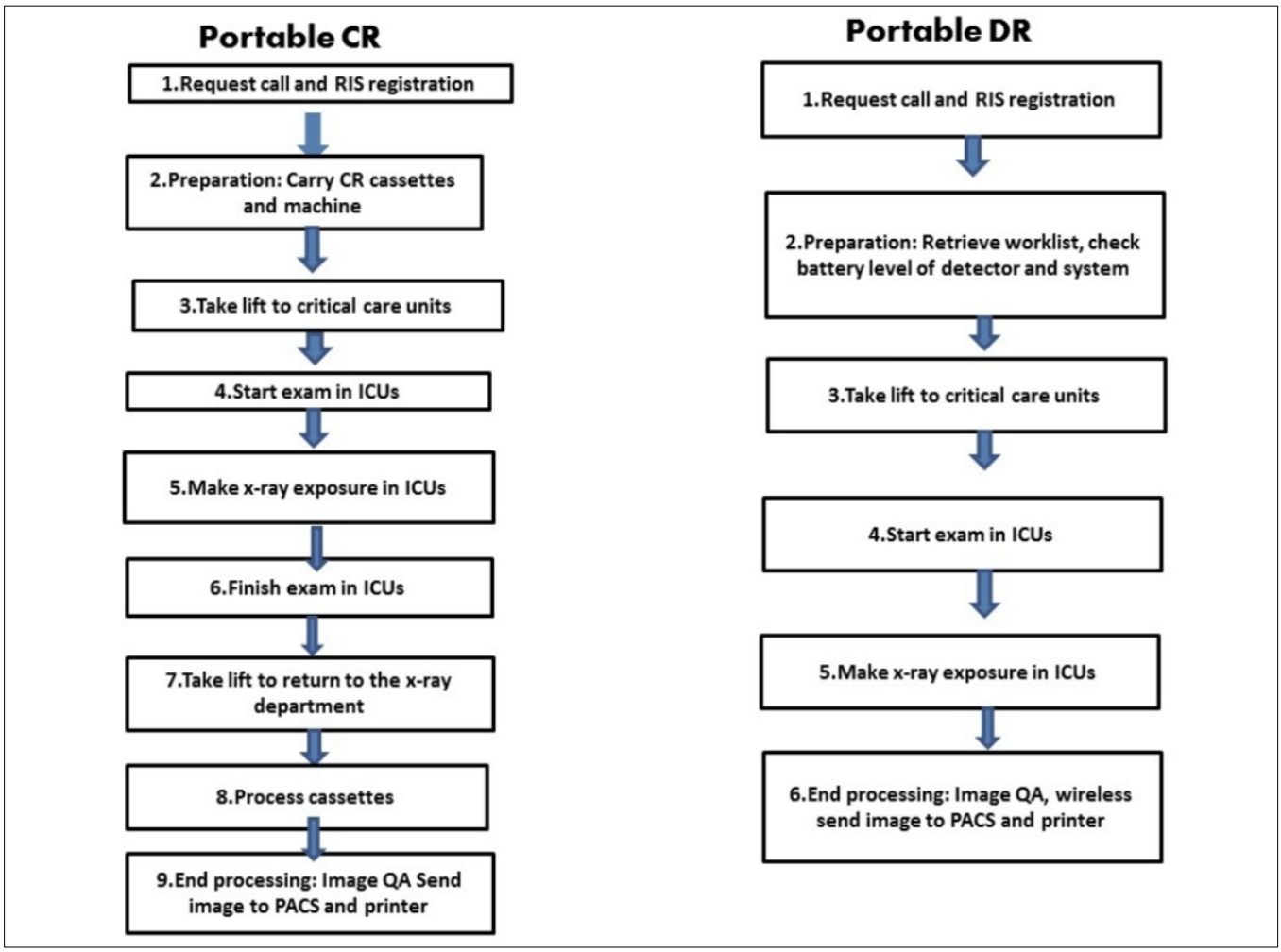

Figure 5 Workflow changes in comparison with Portable CR versus DR

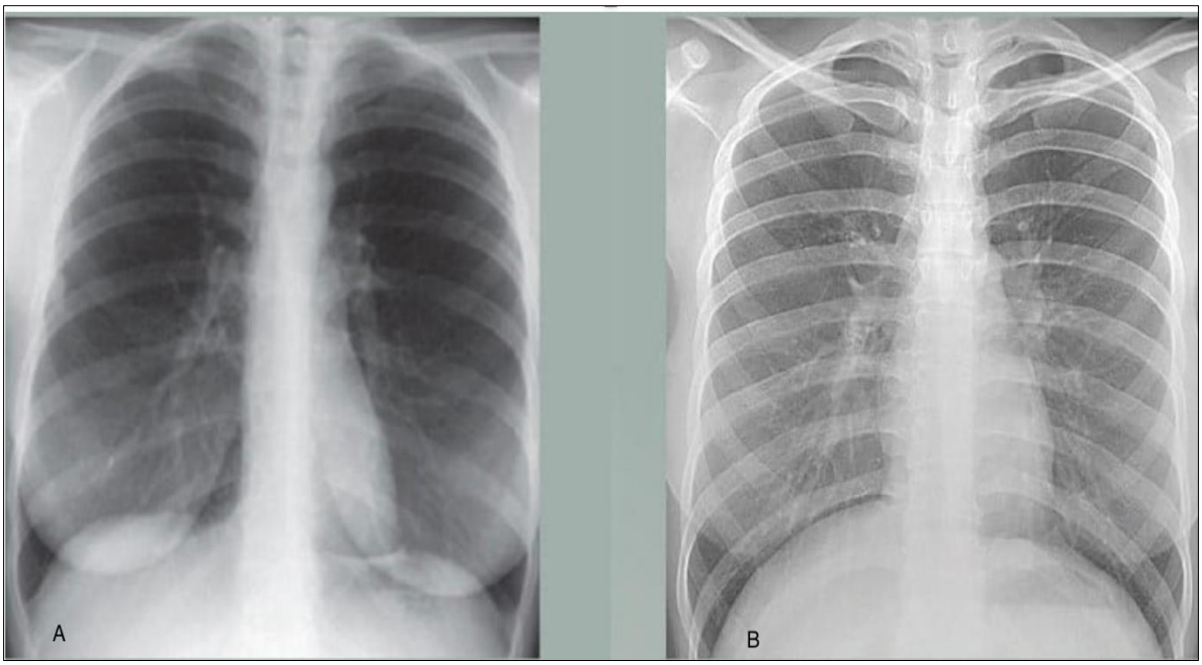

Figure 6 Chest Radiograph taken from Computed x-ray (A) and digital Xray

4. Discussion

This study demonstrates the significant advantages of implementing a retrofitted digital radiography (DR) system in critical care settings, particularly in resource-constrained environments such as those found in many Indian hospitals. The results highlight substantial improvements in workflow efficiency, image quality, and potential clinical outcomes, while offering a cost-effective alternative to full DR system implementation [12-17].

4.1. Workflow Productivity Enhancement

One of the most striking findings of this study is the dramatic improvement in workflow productivity achieved with the retrofitted DR system. The 96% increase in efficiency compared to the computed radiography (CR) system is primarily attributed to significant reductions in examination duration, preparation time, and post-acquisition processing time. These improvements have far-reaching implications for critical care management, where timely decision-making is crucial.

The reduction in examination duration from 51.02 minutes with CR to 15.2 minutes with DR represents a paradigm shift in portable radiography efficiency. This time savings not only improves patient comfort and reduces the disruption to critical care routines but also allows for more frequent imaging when clinically necessary, potentially leading to earlier detection of complications or changes in patient status.

The shortened preparation and post-acquisition processing times with DR (6.8 and 4 minutes, respectively) compared to CR (9.9 and 25.3 minutes) demonstrate the streamlined workflow achievable with digital systems. This efficiency gain can be particularly valuable during high-volume periods or in emergency situations where rapid image availability is essential.

4.2. Treatment Response Time and Clinical Implications

The significant reduction in treatment response time from 14.7 minutes with CR to 3 minutes with DR is perhaps one of the most clinically relevant findings of this study. In critical care settings, where patients' conditions can change rapidly, this 11.7-minute difference can be life-saving. Faster image availability allows for more timely interventions, such as adjustments to ventilator settings, repositioning of lines or tubes, or initiation of treatments for newly identified complications like pneumothorax.

While our study did not directly measure clinical outcomes, the potential for improved patient care is evident. The combination of faster image acquisition, superior image quality, and reduced need for retakes not only enhances

diagnostic accuracy but also minimizes radiation exposure – a crucial consideration in patients requiring frequent imaging. [Fig 7]

4.3. Cost-Effectiveness and Resource Utilization

The retrofitted DR system presents a compelling solution to the financial constraints often faced by healthcare institutions in developing countries. By leveraging existing portable X-ray units, this approach significantly reduces the capital investment required for transitioning to digital radiography. The elimination of film-related costs, reduced equipment maintenance needs, and optimized staff utilization further contribute to the cost-effectiveness of this solution.

Moreover, the improved workflow efficiency allows for better allocation of human resources, potentially addressing staff shortages common in many healthcare settings. The time saved in image acquisition and processing can be redirected to other critical patient care activities, enhancing overall ICU efficiency.

4.4. Image Quality and Diagnostic Accuracy

Although not quantitatively measured in this study, the superior image quality offered by DR systems is well-documented in the literature. The ability to manipulate digital images post-acquisition, adjust contrast and brightness, and zoom in on areas of interest can significantly enhance diagnostic accuracy. This is particularly crucial in critical care settings where subtle changes in lung fields or the position of lines and tubes can have significant clinical implications.

The reduced need for retakes not only decreases radiation exposure but also minimizes patient discomfort and the risk of complication associated with repeated patient positioning, especially in intubated or severely ill patients.

4.5. Integration with Hospital Information Systems

The seamless integration of the retrofitted DR system with PACS and mobile applications for image review represents a significant advancement in critical care imaging. This integration enhances accessibility and collaboration among healthcare providers, allowing for remote consultations and faster decision-making. In resource-limited settings, this capability can be particularly valuable, enabling expertise to be shared across different hospital units or even between institutions.

4.6. Limitations and Future Directions

While our study demonstrates clear advantages of the retrofitted DR system, it is important to acknowledge its limitations. The study was conducted in a single institution and focused primarily on workflow metrics rather than clinical outcomes. Future research should aim to quantify the impact of this technology on patient outcomes, length of ICU stay, and overall hospital costs.

Additionally, long-term studies are needed to assess the durability and maintenance requirements of retrofitted systems compared to purpose-built DR units. Investigation into the potential for further cost reduction through local manufacturing or adaptation of DR components could also be valuable in making this technology more widely accessible in developing countries.

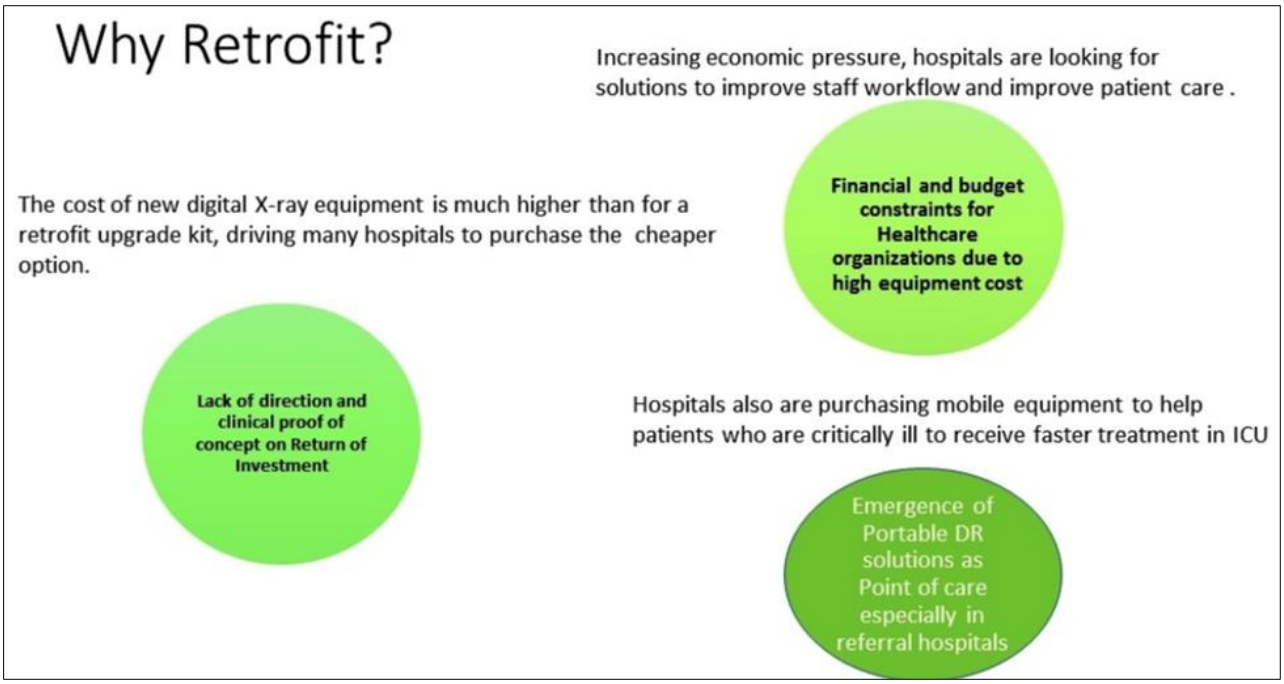

Figure 7 Reference The world market for General Radiography and Fluoroscopy X-ray Equipment- 2013 Sarah jones, medical imaging analysis for IHS

5. Conclusion

Paradoxically, portable DR solutions in the market have demonstrated huge benefits but cost has been a major obstacle to penetration of these systems across the Indian subcontinent. Adopting local innovations, and retrofitting with the existing systems as presented in this study is a reasonable pathway to enable accessibility of such technology without compromising quality and safety.

Our findings shed light on the transformative capacity of retrofitting DR systems in the critical care environment. By enhancing image prompt acquisition, reducing radiation exposure, and diminishing the need for retakes, this technology materially supports fast-tracking decision-making processing and boosts clinical outcomes and patient safety. Simultaneously, this cost-effective shift in practice substantially reduces the consumption of costly films, optimal manpower utilization, and equipment purchases.

Although commercially procurable portable DR systems appear impractical due to their exorbitant price, incentivizing an innovative agenda and quest for cost-effective solutions through retrofitting could stimulate accelerated implementation. Consequently, the transition to an easily accessible and inexpensively produced portable DR technology generation promises a dramatic leap in changing the pattern of critical care imaging in developed countries, embedded in technology-limited environments, eventually optimizing patient treatment patterns and outcomes.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Gupta N, Sharma V, Joshi S, et al. Challenges in providing timely diagnostic imaging in the Indian subcontinent's critical care units. J Crit Care Med. 2016;25(2):22-30. https://doi.org/10.4103/ijccm.IJCCM_287_16

[2] Jindal A, Verma R, Bhatt A. Impact of delayed image processing on critical care patient outcomes. Indian J Radiol Imaging. 2017;27(4):256-261. https://doi.org/10.4103/ijri.IJRI_178_17

[3] Anderson C, Ward J, Wheeler M, et al. Daily chest radiographs in intensive care units: A critical review of their diagnostic value. Chest. 2015;148(6):1237-1244.https://doi.org/10.1378/chest.14-3188

[4] . Patel R, Singh A, Kumar R. The role of immediate chest X-ray imaging in emergency interventions for ICU patients. Intensive Care Med. 2018;44(10):1798-1805. https://doi.org/10.1007/s00134-018-5247-1

[5] Bansal M, Mittal A, Yadav R, et al. Digital radiography for emergency diagnostic imaging in critically ill patients. Eur Radiol. 2019;29(3):1321-1328.https://doi.org/10.1007/s00330-018-5701-y

[6] Dey A, Yadav D, Gupta S. Diagnostic accuracy and image quality: A comparison of digital radiography and computed radiography in intensive care units. Radiol Technol. 2018;89(2):187-193.https://doi.org/10.1016/j.rtech.2017.11.003

[7] Reddy P, Singh B, Mishra S. The impact of Picture Archiving and Communication Systems (PACS) in critical care imaging. J Med Imaging. 2017;24(4):409-415.https://doi.org/10.1117/1.JMI.4.4.041302

[8] Sharma H, Verma R, Pathak S. A comparative study of CR and DR systems in emergency departments. J Med Imaging Radiat Oncol. 2016;40(5):302-309.https://doi.org/10.1111/1754-9485.12450

[9] Patel J, Kumar R, Singh M. Workforce productivity and the impact of DR technology on critical care units. J Intensive Care Med. 2020;35(1):22-29.https://doi.org/10.1177/0885066617738663

[10] Kapoor R, Mishra D, Sharma A. Time-saving and efficiency in diagnostic imaging: The benefits of retrofitting digital radiography in resource-constrained settings. Radiol Manage. 2020;42(2):38-42.https://doi.org/10.1016/j.radmag.2019.12.002

[11] Rani S, Gupta D, Shah S. Patient safety and clinical outcomes with digital radiography systems in intensive care units. J Patient Saf. 2019;15(4):e78-e83. https://doi.org/10.1097/PTS.0000000000000534

[12] Amorosa JK, Bramwit MP, Mohammed TL, et al. ACR appropriateness criteria routine chest radiographs in intensive care unit patients. J Am Coll Radiol. 2013;10(3):170-174.https://doi.org/10.1016/j.jacr.2012.11.013

[13] Henschke CI, Yankelevitz DF, Wand A, et al. Chest radiography in the ICU. Clin Imaging. 1997;21(2):90-103.https://doi.org/10.1016/S0899-7071(96)00026-1

[14] Henschke CI, Yankelevitz DF, Wand A, et al. Accuracy and efficacy of chest radiography in the intensive care unit. Radiol Clin North Am. 1996;34(1):21-31.https://doi.org/10.1016/S0033-8389(05)70332-4

[15] Kotter E, Langer M. Digital radiography with large-area flat-panel detectors. Eur Radiol. 2002;12(10):2562-2570.https://doi.org/10.1007/s00330-002-1350-1

[16] Ngan TL, Wong ETH, Ng KLS, et al. The Enhanced Workflow and Efficiency of the Wireless Local Area Network (WLAN)-Based Direct Digital Radiography (DDR) Portable Radiography. J Digit Imaging. 2015;28(3):302-308. https://doi.org/10.1007/s10278-014-9741-9

[17] Uffmann M, Schaefer-Prokop C. Digital radiography: The balance between image quality and required radiation dose. Eur J Radiol. 2009;72(2):202-208. https://doi.org/10.1016/j.ejrad.2009.05.060