RADIOGRAPHIC IMAGE QUALITY ANALYSIS IN THORAX, ABDOMEN, AND BONE FRACTURE EXAMINATIONS WITH KV AND MAS PARAMETER VARIATIONS

Zahra Putri Rahman[1], Ramdhani Syahputra[2],Nani Lasiyah[3]*
[1,2,3]Institut Kesehatan dan Teknologi Al Insyirah, Pekanbaru
Corresponding E-mail: nani.lasiyah@ikta.ac.id[1]* , ramdhani@ikta.ac.id[2]

Received	: 21 April 2025	Published	: 12 June 2025
Revised	: 30 April 2025	DOI	: https://doi.org/10.54443/morfai.v5i4.3147
Accepted	: 15 May 2025	Link Publish	: https://radjapublika.com/index.php/MORFAI/article/view/3147

Abstract

This experimental study at Petala Bumi Public Hospital (Jan–Apr 2025) aimed to determine the optimal tube voltage (kV) and tube current–time product (mAs) settings to enhance conventional X-ray image quality for thoracic, abdominal, and bone fracture examinations. Radiographs were taken using varied kV–mAs combinations and analyzed with ImageJ software through grey-level histograms to assess brightness (mean pixel intensity) and contrast (standard deviation). The thoracic image with a mean of 127.117 and SD of 83.331 showed the best balance of brightness and contrast. The optimal abdominal image had a mean of 107.703 and SD of 66.725, while the best bone fracture image had an SD of 65.463, ensuring clear fracture visibility. The study confirms the effectiveness of ImageJ in objective image-quality evaluation and highlights the importance of adjusting exposure parameters to improve diagnostic clarity without increasing radiation dose.

Keywords: ***Conventional X-ray, image quality, tube voltage (kV), tube current–time product (mAs), ImageJ,, radiation dose.***

INTRODUCTION

Advances in radiological technology have significantly enhanced diagnostic accuracy, yet conventional X-ray imaging remains indispensable in clinical practice due to its rapid acquisition, operational simplicity, and cost-effectiveness. High-quality radiographs are critical for accurate diagnosis in thoracic, abdominal, and bone fracture examinations; however, image quality is largely determined by two key exposure parameters: tube voltage (kilovoltage peak, kV), which governs photon energy, and tube current–time product (mAs), which controls photon flux (Hyperastuty, 2023). An imbalance in these parameters can compromise image contrast and spatial resolution or elevate patient radiation dose, ultimately increasing the risk of misinterpretation, diagnostic delay, and repeated imaging. Prior investigations have elucidated the individual roles of exposure variables. Azis et al. (2019) demonstrated that variations in tube current (mA) yield significant changes in radiographic contrast and sharpness, though their study did not assess concurrent adjustments in kV. Conversely, Hyperastuty (2023) highlighted that an optimized kV–mAs pairing can achieve diagnostically superior images while maintaining patient safety. Despite these insights, comprehensive evaluations of combined kV and mAs effects across different anatomical examinations remain scarce. This study therefore aims to analyze the synergistic impact of tube voltage and tube current–time product on conventional X-ray image quality in thoracic, abdominal, and bone fracture assessments. By identifying optimal kV–mAs combinations, we seek to develop practical guidelines for radiology practitioners that ensure maximal diagnostic clarity with minimal radiation exposure to patients.

LITERATURE REVIEW

Advances in conventional X-ray imaging have continued to play a pivotal role in medical diagnostics due to its wide availability, rapid acquisition, and cost-effectiveness. However, optimizing image quality while minimizing patient dose requires careful adjustment of two core exposure parameters: tube voltage (kV), which determines photon energy, and tube current–time product (mAs), which controls photon flux. Numerous studies have explored these variables in isolation or limited combinations, but few have systematically evaluated their joint effects across different anatomical examinations.

Dewi, Ratini, and Trisnawati (2020) varied kV settings (80, 100, 120 kV) on a CT phantom to measure contrast-to-noise ratio (CNR), finding that lower kV (80 kV) yielded the highest CNR—suggesting improved contrast at the expense of potentially higher dose. Their work, however, was limited to CT rather than conventional radiography and did not assess image detail beyond CNR. Bebbington et al. (2021) evaluated Siemens' CARE automatic kV selection on PET-CT phantoms, demonstrating that automated kV reduction could lower patient dose without degrading image contrast; yet, this study focused on hybrid PET-CT and lacked assessment of manual parameter optimization in plain X-ray systems.

Azis and Nababan (2019) conducted an experimental study on a General Allenger X-ray unit by varying mA (50, 100, 150, 200 mA) at fixed kV and focus-film distance. They showed that increasing mA darkened film density and improved perceived sharpness, identifying 50 kV, 100 mA, and 0.25 s as their "optimal" setting. While insightful, the study did not vary kV concurrently, leaving open how kV–mAs interactions might further enhance or impair image quality. More recently, Fitriani, Zelviani, and Sahara (2022) compared "standard" (50–70 kV) versus "high" (90–110 kV) settings for chest radiographs at constant 10 mAs and 100 cm source-image distance; they concluded that standard kV yielded better object-to-background contrast, whereas high kV reduced contrast differentiation. Their design, though focused on thoracic imaging, again held mAs constant, thus not capturing the full parameter space.

Theoretical Frameworks and Image-Quality Metrics.

Across these studies, image quality has been characterized by metrics such as CNR, film density, and subjective sharpness ratings. Underpinning these metrics is the physics of X-ray attenuation and detector response: higher kV increases beam penetration and reduces contrast, while higher mAs increases photon count and reduces quantum noise but raises dose linearly (Seibert & Boone, 2017). This framework suggests a trade-off curve: too low kV yields high contrast but excessive noise; too low mAs yields noisy images; too high either parameter increases unnecessary dose.

Debate persists over the optimal balance: Dewi et al. (2020) advocate lower kV for contrast, whereas Fitriani et al. (2022) warn of contrast loss at high kV. Automated kV selection (Bebbington et al., 2021) addresses this by tailoring parameters per patient, but requires proprietary software and may not suit all clinical settings. No consensus exists for conventional X-ray units lacking automation, especially across varying anatomical regions (thorax vs. abdomen vs. bone).

While prior work has illuminated single-parameter effects or automated approaches, there remains a clear gap in systematic, manual optimization of combined kV–and mAs settings across different radiographic examinations. Our study addresses this by acquiring thoracic, abdominal, and fracture radiographs under multiple kV–mAs pairings, analyzing objective image-quality metrics (mean pixel intensity and standard deviation) via ImageJ. By mapping these parameters to diagnostic clarity and dose implications, we will provide actionable guidelines for radiology practitioners using conventional X-ray systems without automation—bridging the current divide between single-parameter studies and fully automated solutions.

METHOD

This research employs an experimental design to analyze conventional X-ray image quality at Petala Bumi Hospital Pekanbaru's radiology department. The study spans four months from January to April 2025, focusing on three types of medical images: thorax, bone fracture, and abdominal images. The research progresses systematically through permit preparation, equipment setup, data collection with hospital radiographers, image processing using ImageJ software, and comprehensive quality analysis.

OPEN ACCESS

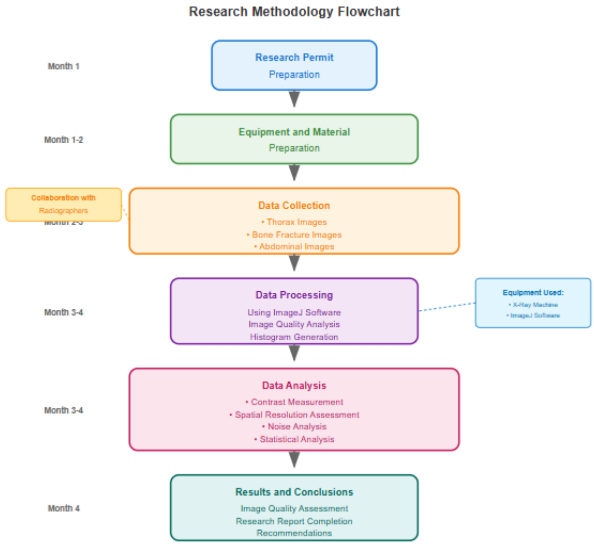

Image 1.Research Methodology Flowchart

The primary equipment includes a conventional X-ray machine for image acquisition, ImageJ software for data processing and quality analysis, and a laptop computer for computational tasks. The X-ray machine serves as the main testing instrument, while ImageJ provides comprehensive tools for measuring image quality parameters including contrast, brightness, spatial resolution, and histogram analysis. Data collection involves systematic acquisition of X-ray images under controlled conditions in collaboration with hospital radiographers. Each ima ge category requires specific technical parameters optimized for diagnostic quality. The process includes direct measurement and data capture from the conventional X-ray equipment, generating both image files and corresponding histograms for subsequent analysis. The analysis employs quantitative methods using ImageJ software to evaluate image quality parameters. Key measurements include contrast assessment through light-dark area differentiation, spatial resolution analysis for object distinction capability, noise quantification for unwanted intensity variations, and statistical histogram examination of pixel intensity distribution. Results are analyzed through descriptive statistics, comparative analysis between image types, and correlation studies between technical parameters and quality outcomes to determine optimal imaging conditions for each X-ray category.

RESULTS AND DISCUSSION

The radiographic image results of thorax, abdomen, and bone fracture in this study can be seen in Figure 3.1, while the histogram results from thorax, abdomen, and bone fracture examinations are shown in Figure 3.2.

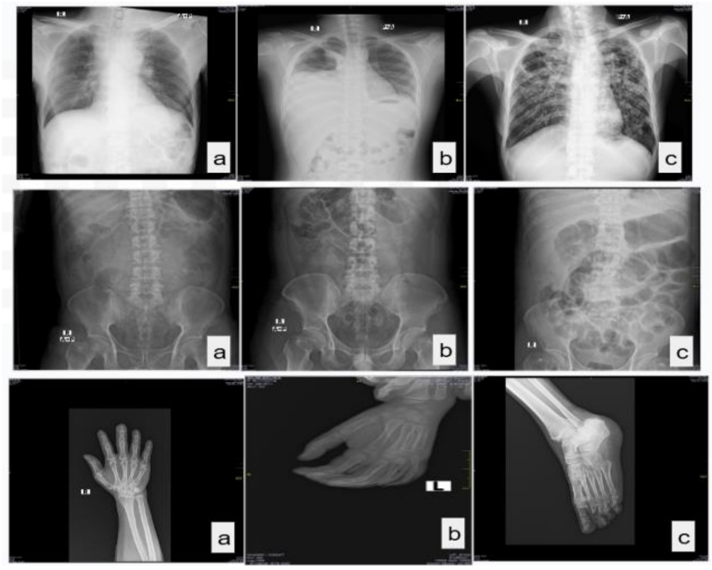

Figure 3.1 Radiographic Image Results of Thorax, Abdomen, and Bone Fracture

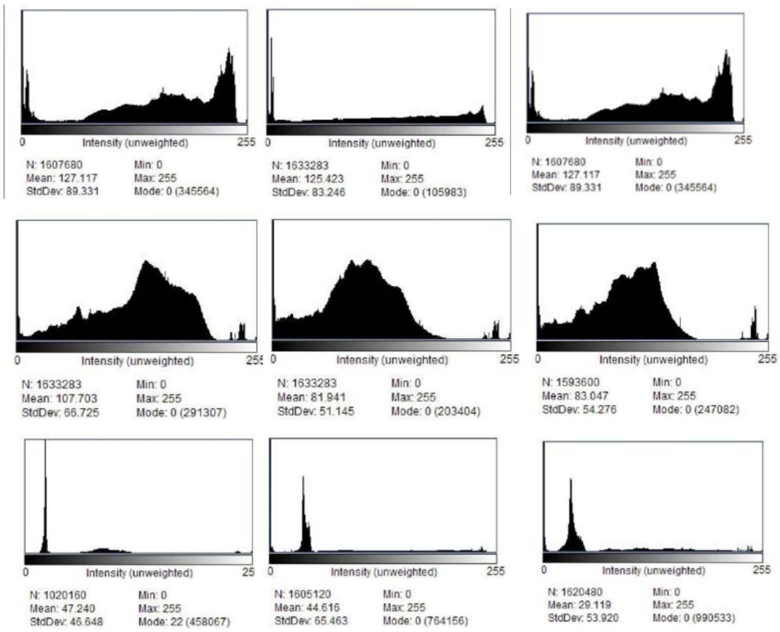

Figure 3.2 Histogram Results of Thorax, Abdomen, and Bone Fracture Radiography

This study evaluates the quality of conventional X-ray images based on radiological examination results of thorax, abdomen, and bone fracture (ossa), using ImageJ software to analyze grey level histograms. The assessed parameters include mean value (brightness), standard deviation (contrast), and pixel intensity distribution. The thorax image (c) demonstrates the most optimal quality. The histogram shows an even grey level distribution with two peaks (dark and bright), a mean of 127.117, and standard deviation of 83.331. This indicates excellent illumination and contrast levels for visualization of chest anatomical structures. The abdomen image (a) has a mean of 107.703 and standard deviation of 66.725, showing sufficiently bright illumination and good contrast. The balanced pixel distribution supports visual clarity of internal organs.

Image (b) has an even intensity distribution with the highest standard deviation (65.463), indicating adequate contrast and near-ideal illumination. This supports bone structure clarity for fracture identification. These results align with the study by Sparzirnanda et al. (2024) which demonstrated that voltage (kV) and current (mAs) increases affect image quality through grey-scale histograms. Although their research used water phantoms and controlled exposure, while this study uses actual clinical data from thorax, abdomen, and ossa images, both studies equally show that exposure parameters significantly influence diagnostic image quality. This research also complements the findings of Yusalim Azis et al. (2019) which emphasized the importance of mAs settings on image quality. By adding object variation and evaluating more than one exposure parameter (kV and mAs), this study provides a more comprehensive overview of clinical X-ray image quality optimization.

CONCLUSION

The research demonstrates that ImageJ software is effective and user-friendly for analyzing X-ray image quality through grey level histograms. Image quality is significantly influenced by kV and mAs variations, where the best images are characterized by balanced histograms, moderate intensity means, and standard deviations that reflect optimal contrast. Appropriate exposure parameters produce clearer and more accurate diagnostic images.

REFERENCES

Azis, y., & nababan, s. (2019). Analisa faktor ma pada pesawat x-ray general merk allengers type 325. Jurnal mutiara elektromedik, 3(2), 32–37.

Badan Pengawas Tenaga Nuklir. (2019). Buku Panduan Perizinan Pesawat Sinar-X Radiologi Diagnostik dan Intervensional. Jakarta: Subdirektorat Perizinan Fasilitas Kesehatan, Direktorat Perizinan Fasilitas Radiasi dan Zat Radioaktif.

Bebbington, N. A., Jørgensen, T., Dupont, E., & Micheelsen, M. A. (2021). Validation of CARE kV automated tube voltage selection for PET-CT: PET quantification and CT radiation dose reduction in phantoms. EJNMMI Physics, 8(29).

Brenda Putri Meliana, Arif Wahyu Setyo Budi, & Rahmawanto. (2024). Pengaruh Pemasangan Balut Bidai dan Relaksasi Nafas Dalam terhadap Penurunan Skala Nyeri pada Pasien Fraktur.

Dewi, P., Ratini, N., & Trisnawati, N. (2022). Effect of x-ray tube voltage variation to value of contrast to noise ratio (cnr) on computed tomography (ct) scan at rsud bali mandara. International Journal of Physical Sciences and Engineering, 6(2), 82-90.

Endah Savitri, R., & Sunarno. (2014). Optimasi Faktor Eksposi Pada Sistem Radio Optimasi Faktor Eksposi Pada Sistem Radiografi Grafi Digital Menggunakan Analisis CNR (Contrast To Noise Ratio). Unnes Physics Journal.

Fitriyani, F., Suharyana, Muhtarom, Riyatun (2017). Pengaruh focus film distance terhadap kesesuaian berkas radiasi pada pesawat x-ray simulator di instalasi radioterapi rsud dr. Moewardi surakarta.

Gustia, r. M. (2021). Analisis sebaran radiasi hambur pesawat sinar x konvensional di instalasi radiologi rsia zainab.

Prasetyo. B.D. 2020. Klasifikasi Citra X-Ray Paru-Paru Anak Pneumonia Dan Non-Pneumonia Menggunakan Metode Segmentasi Dan Deteksi Tepi.

Prastanti A. D., Abimanyu B., Nino A., (2020). Optimasi citra cr dan limitasi dosis dengan pengaturan kolimasi pada radiograf servikal. Rasad, Sjahriar. 2016. Radiologi Diagnostik. Jakarta:Balai Penerbit FKUI.

OPEN ACCESS