KUALITAS CITRA RADIOGRAFI DIGITAL PADA SACRUM DIPENGARUHI FAKTOR EKSPOS SINAR-X

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Abstract

Digital radiography of the sacrum requires precise adjustments of exposure parameters (kV, mA, time) to produce high-quality images while minimizing radiation exposure. This study aims to investigate how these exposure factors affect the quality of sacral images and to recommend optimal settings that align with radiation safety principles such as ALARA. By reviewing the existing literature, it was found that the modification of exposure parameters (kV, mA, time) in digital radiography is essential for achieving optimal image quality while minimizing radiation exposure. The exposure index (EI) serves as an indirect measure of the dose absorbed by the detector, thereby facilitating the implementation of the ALARA principles. Properly orienting the AEC chamber can reduce radiation dose by up to 44% without compromising image quality. Tube voltage and current adjustment enhances image contrast and sharpness. Nonetheless, inconsistent exposure methods and dependence on presets can still lead to dose creep. It is essential to train radiographers, adjust equipment settings, and set Diagnostic Reference Levels (DRLs) to enhance imaging quality and ensure patient safety. In digital radiography, factors such as tube voltage (kV), tube current (mA), and exposure time (s/mAs) significantly affect image quality and patient radiation dose. Adjusting exposure settings according to patient characteristics and exam objectives enhances image quality and reduces radiation exposure, particularly in sensitive areas like the sacrum. Technologies such as Exposure Index (EI), Automatic Exposure Control (AEC), and image analysis software facilitate an objective method that follows the ALARA principle, ensuring patient safety while optimizing diagnostic outcomes.

Keywords: Digital radiography (DR), sacrum, radiation dose, exposure index, personalised optimisation.

1. Background

Medical imaging using digital radiography technology has become one of the main methods in diagnosing various clinical conditions, including spinal examinations, such as the sacrum. Another factor that determines the quality of radiography is the exposure factor. The exposure factor is the factor that influences and determines the quality and quantity of X-ray radiation exposure needed in the production of radiographic images (Sartinah et al., 2008). Exposure factors consist of tube voltage (kV), tube current (mA), and exposure time (s) (Rasad, 2005).

Proper adjustment of exposure factors can produce optimal radiographic contrast, capable of showing clear differences in degrees of radiopacity between organs with different densities (Dhahryan and Azam, 2009).

Providing the correct exposure factors can reduce the absorbed radiation exposure while considering the visual quality of the radiographic image. While advancements in digital radiography technology offer numerous advantages, particularly regarding resolution and contrast, we still have a limited understanding of how exposure factors affect image quality. In sacrum imaging, the quality of the resulting image is greatly affected by the correct exposure settings, as the sacrum is a complex anatomical structure with varying tissue densities. Unclear or distorted images can hinder the detection of abnormalities in the bone structure, which may reduce diagnostic accuracy. Additionally, improper radiation exposure can increase the risk of side effects in patients, such as increased radiation exposure that poses a health risk; therefore, the use of radiation protection principles like ALARA is necessary.

This investigation focuses on the elements that affect the quality of X-ray images of the sacrum. Furthermore, what measures can be taken to minimize the radiation dose received by the patient? Which modifications to the exposure parameters are considered suitable? The aim of this study is to analyze the exposure factors influencing sacral X-ray imaging, to outline the principles of radiation safety, and to determine the best exposure settings as recommendations for sacral imaging in line with established radiation protection standards.

2. Method

This type of research uses a literature review method, with a study conducted on a total of 9 local and international literatures. Data collection was conducted through Google Scholar, PubMed, Science Direct, and Neliti using several keywords such as digital radiography, exposure, exposure factors, radiation dose, sacrum, image quality. The data collection method used in this study is the theoretical study/library study method. The analysis of the collected data was conducted descriptively by creating a narrative of relevant journals and comparing them with theories, from which conclusions and recommendations can be drawn afterward. The focus of this literature review is on how to produce imaging of the sacrum based on the principles of radiation protection.

3. Results and Discussion

Result:

In the study conducted by J. Anthony Seibert and Richard L. Morin (2011) According to international standards developed by the International Electrotechnical Commission (IEC) and the American Association of Physicists in Medicine (AAPM), the use of exposure index does not directly indicate the dose received by the patient, but provides a linear estimate of the radiation exposure received by the detector.

The utilization of this standardized exposure index is anticipated to improve the uniformity of radiography technicians in modifying exposure parameters, including kVp, mAs, and exposure duration. This aligns with the principle of ALADAIP (As Low As Diagnostically Achievable being Indication-oriented and Patient-specific), which underscores the necessity of accurately calibrating radiation exposure according to clinical indications and patient attributes, particularly in the assessment of the sacral region, which is prone to exposure inaccuracies.

Thus, the enhancement of diagnostic image quality can be accomplished without elevating unnecessary radiation risks, particularly in pediatric populations and patients with particular indications.

The research conducted by Anthony S Manning-Stanley et al (2012) aims to evaluate the influence of phantom pelvis orientation and the selection of the Automated Exposure Control (AEC) chamber on radiation dose and image quality (IQ) in digital radiography (DR) examinations. The study was conducted using an Alderson-type anthropomorphic pelvis phantom and the GE Definium 6000 digital radiography unit equipped with a 41 × 41 cm amorphous silicon flat-panel detector, cesium-iodide scintillator, and a TFT array with a resolution of 2048 × 2048 pixels and a pitch of 0.2 mm.

The study compared two orientations of the AEC chamber:

- Cr-AEC: orientation of the outer AEC chamber cranially (according to general recommendations)
- Ca-AEC: orientation of the outer AEC chamber in a caudal direction

All combinations of AEC settings were tested. The exposure parameters used include a fixed mAs value and variations in Source to Skin Distance (SSD) and voltage (kVp). The radiation dose is calculated based on Entrance Surface Dose (ESD) and Effective Dose (ED). Image quality assessment was conducted by two observers on six anatomical areas using a three-point scale.

The research results indicate that by changing the orientation of the phantom from Cr-AEC to Ca-AEC, there was a 36.8% reduction in the average radiation dose. This decrease is accompanied by a slight reduction in image quality (median IQ: 15.5 to 15.0), which still falls within the "acceptable" category for diagnostic interpretation. In the Ca-AEC orientation, the use of the outer AEC chamber alone allows for a dose reduction of up to 44%, whereas in the Cr-AEC orientation, the use of the central AEC chamber (alone or in combination) allows for a dose reduction of up to 11%. It should be noted that in the Ca-AEC orientation, only 1.6% of the images were assessed to have all anatomical areas in the "unacceptable" category by one observer.

The rest showed adequate image quality. In the discussion, it was explained that the lateral position of the AEC chamber, which is not covered by bone structures in the Ca-AEC orientation, results in more accurate and efficient dose readings. This study highlights the importance of actively selecting the position of the AEC and the orientation of the patient/phantom in the effort to optimize radiation dose, in accordance with the ALARA/ALARP principle. It is recommended that the position of the AEC chamber be marked on radiographic equipment (for example, with stickers on the bucky or table) to facilitate proper orientation based on examination needs, thereby enabling individual image optimization.

Fadden et al (2017) in their research aimed at identifying variations in radiographic knowledge and practices across Europe, particularly in chest, abdomen, and pelvis imaging using digital imaging technologies such as Computed Radiography (CR) and Digital Radiography (DR). The main focus is on the understanding and application of the ALARA (As Low As Reasonably Achievable) principle as well as awareness of Diagnostic Reference Levels (DRLs). A total of

17 educational institutions that are members of the European Federation of Radiographer Societies (EFRS) participated by filling out an online survey using the SurveyMonkey platform. The results of this study revealed differences in the training and education of radiographers across various countries, with significant variations in image processing practices using CR and DR. Some radiographers also reported reliance on pre-set exposure settings and rarely adjusted exposure factors for patients of different body sizes. This study highlights the need for standardization in the education and training of radiographers, including protocols and exposure parameters, to ensure compliance with the ALARA principle. Variations in practices and knowledge indicate the need for a unified approach across Europe to enhance the quality and safety in diagnostic radiography practices.

The research conducted by Eif Sparzinanda, Nehru, Nurhidayah (2018) aims to determine the extent of the exposure factor's influence on the quality of radiographic images. This study uses a mobile X-ray machine module with the brand Villa Sistemi Medicalli type/model Visitor T30C, a set of Computed Radiography (CR), and CR cassettes. Meanwhile, the material used is an air phantom placed inside plastic. Exposure settings were adjusted with variations in tube voltage (60 kV, 65 kV, 70 kV, 75 kV, 80 kV) and current time (20 mAs, 25 mAs, 30 mAs). The object is positioned 100 cm from the X-ray tube with an irradiation field size of 15 cm x 15 cm. After exposure, the image formed on the CR cassette will be read using an imaging plate reader, then processed into a digital signal and analyzed using Image-J software. Data is analyzed based on contrast and image sharpness parameters as well as the grayscale histogram to obtain information on the distribution of gray level intensity. The research results show that at each variation of voltage and current time, the radiographic images exhibit a quite significant difference in quality. Images with low tube voltage (60 kV) and appropriate current time (20 mAs) provide better contrast and image sharpness. On the other hand, the use of high voltage (80 kV) with long current time (30 mAs) results in a decrease in image quality, as seen from the darker and less sharp images.

Gray level histogram analysis using Image-J software provides a clear picture of the distribution of image gray intensity. The analysis results show that images with the best contrast and sharpness fall within a more balanced gray level range, while low-quality images tend to have a gray level distribution more concentrated in the dark areas.

This study emphasizes the importance of proper exposure factor settings to achieve optimal radiographic image results, thereby minimizing unnecessary radiation and improving diagnostic quality. Overall, to achieve optimal radiographic image quality, proper adjustments to tube voltage and time current are necessary according to the examination requirements and the condition of the object to be examined.

The study conducted by Lewis et al. (2019) This research is motivated by concerns about the presence of undetected exposure technique variations in DR practice. In the film-screen system, exposure errors are more easily recognized because they affect the visual quality of the film. However, in DR, post-processing technology allows images to still look "good" even with incorrect exposure techniques, which risks increasing "dose creep" — a trend of gradually and unconsciously increasing radiation doses. This research is a retrospective pilot study that analyzes EI data from various radiographs taken in clinical practice.

The aim is to determine whether EI can be used as a reliable indicator to evaluate the exposure techniques used by radiographers. The study results show that there is a significant variation in EI values, indicating inconsistency in exposure techniques. The main result of this study shows that only a portion of the images have an EI value within the target range. Most are outside the recommended range, with a significant proportion in the overexposure category. This indicates a trend of "dose creep," which is the use of exposure techniques that exceed clinical needs to ensure image quality remains good. Although image quality is not significantly affected by variations in EI due to digital processing, a high EI value indicates that the patient is receiving a higher radiation dose than necessary. This condition not only contradicts the ALARA (As Low As Reasonably Achievable) principle but also indicates the need for intervention in the training and supervision of exposure techniques by radiographers.

Welarathn et al (2022) in their research used Diagnostic Reference Levels (DRLs) as an optimization tool to identify unusually high or low patient doses during X-ray examinations. The main objective of this study is to propose institutional Diagnostic Reference Levels (IDRLs) by measuring the kerma-area product (KAP) in adult patients undergoing routine projection X-ray examinations.

This study involves at least 400 adult patients aged between 18 and 87 years with an average weight of 58 ± 20 kg. With various types of tissue projections to determine which areas have the lowest and highest values, the midpoint of the collected data will then be sought and established as the new standard. This data is crucial to ensure dose optimization to maintain adequate patient radiation protection principles. This study recommends enhancing the training of radiology technologists, calibrating equipment, and conducting routine internal audits to reduce dose variation.

Based on the research conducted by Yufita et al (2023), which aims to analyze the influence of exposure factors on the optical density of radiographic film images produced using the Java platform software Image-J Basics version 1.38. The samples used to represent the tissues in the body are bone, fat, jelly, and additional samples such as iron and aluminum (coins) were also used. The container used for placing the samples is made of acrylic. The exposure settings employed in this study included variations in tube voltage, specifically at levels of 60kV, 70kV, 75kV, and 85kV. Additionally, the tube current was adjusted to different values of 20mA, 25mA, and 32mA. To determine the optical density value, we analyzed the segmentation of the film image that was captured from an acrylic holder containing five samples. This analysis was conducted using Image-J software, which facilitated the extraction of the necessary data for our evaluation. From the experiment, it was found that the exposure factor significantly affects the optical density value of each sample. The combination to achieve the most optimal optical density was at a current of 20mA with a voltage of 60 kV. At a current of 25 mA, the most optimal optical density is at a voltage of 70 kV. At a current of 32 mA, the optimal optical density is at a voltage of 70 kV.

Disccusion

Exposure factors in digital radiography—including tube voltage (kV), tube current (mA), and exposure time (s/mAs)—play a crucial role in determining image quality and the amount of radiation dose received by the patient. The results of studies from various analyzed literature indicate that suboptimal exposure can directly impact both image quality and the level of radiation exposure received by the patient, which, if not controlled, will contradict the ALARA (As Low As Reasonably Achievable) radiation protection principle.

This principle emphasizes the importance of administering the smallest possible radiation dose to achieve diagnostic goals, without compromising image quality, and adjusting exposure based on clinical needs, patient conditions, and examination objectives.

A study by Seibert and Morin (2011) highlights the importance of using the Exposure Index (EI) as an indicator of the estimated radiation exposure received by the detector, rather than the patient directly. By applying a standardized Exposure Index (EI), technicians can consistently adjust exposure factors such as kVp, mAs, and exposure time, supporting the ALADAIP principle (As Low As Diagnostically Achievable being Indication-oriented and Patient-specific), which emphasizes dose adjustment based on clinical indications and individual patient characteristics. This approach is highly relevant for anatomy such as the sacrum, which is sensitive to exposure errors.

Furthermore, Manning-Stanley et al. (2012) demonstrated that the orientation settings of the object and the selection of the Automated Exposure Control (AEC) chamber significantly affect the dose magnitude and image quality. The Ca-AEC orientation results in a dose reduction of up to 36.8% compared to Cr-AEC, with minimal image quality degradation and remaining within acceptable diagnostic limits. This shows that exposure configurations should not be default but need to be actively adjusted based on the examined anatomical structure and clinical objectives, supporting the principle of radiation protection optimization.

A study by Eif Sparzinanda et al. (2016) reinforces the importance of exposure settings by showing that the use of low voltage (60 kV) and moderate current (20 mAs) provides the best contrast and image sharpness in a Computed Radiography (CR) system using mobile X-ray. On the other hand, the high exposure combination (80 kV/30 mAs) actually produces darker and less sharp images, and has the potential to cause overexposure. This indicates the need for a balance between image quality and radiation dose to avoid unnecessary dose increases.

Yufita et al. (2023) also found a direct correlation between the combination of exposure factors and optical density in radiographic film images. The optimal combination varies depending on the type of test material representing body tissue, emphasizing that each object requires a specific exposure and cannot be equated between patients or between examinations. This variation underscores the importance of individual and data-driven exposure parameter adjustments, rather than mere habits or fixed protocols. Overall, from the entire analyzed literature, it can be concluded that optimal exposure settings highly depend on adaptation to patient characteristics, anatomical projections, and the imaging technology used.

Radiation protection principles such as ALARA, ALARP (As Low As Reasonably Practicable), and ALADAIP form the foundation in ensuring that each radiation exposure is kept at a minimal level while still producing images that are adequate for diagnosis. Additionally, the use of supporting technologies such as AEC, monitoring EI values, and analysis software like Image-J provides a more objective data-driven approach in exposure decision-making, rather than relying solely on the subjective experience of technicians. This way, the risk of "dose creep" that often occurs in digital radiography systems can be minimized as much as possible.

The implementation of this principle is crucial, especially in imaging sensitive areas such as the sacrum, to maintain diagnostic quality without compromising patient safety.

Conclusion and suggestion

Conclusion:

Based on the literature review conducted, it can be concluded that exposure factors in digital radiography—including tube voltage (kV), tube current (mA), and exposure time (s/mAs)—play an important role in determining the quality of sacrum radiographic images as well as the amount of radiation dose received by the patient. Improper exposure settings can not only reduce image quality, such as decreased contrast and sharpness, but also increase the risk of excessive radiation exposure, especially in complex and sensitive areas like the sacrum.

Research indicates that combining low voltage with suitable current levels can yield optimal image quality while reducing radiation exposure. Additionally, employing a standardized Exposure Index (EI), utilizing Automated Exposure Control (AEC), and implementing software-based analysis methods like Image-J have been shown to effectively enhance exposure optimization. Adjustment of exposure techniques must be individualized, considering patient characteristics, examination goals, and the complexity of the anatomy being examined. Radiation protection principles such as ALARA, ALADAIP, and ALARP are fundamental in making exposure decisions to ensure patient safety without compromising diagnostic quality.

Suggestion:

Based on the study results, it is recommended that radiographers be more proactive in evaluating and adjusting exposure parameters individually based on the patient's condition and the type of projection used, particularly for sacrum imaging which has a variety of tissue densities. The use of supporting technologies such as AEC should be optimized by considering the orientation and selection of the appropriate chamber to reduce the dose without compromising image quality.

Additionally, it is important to implement Exposure Index usage standards in clinical practice to accurately monitor potential overexposure and avoid "dose creep." Local standardization, continuous training, and increased awareness of radiation protection principles are absolutely necessary for all radiographers, including the importance of internal audits and regular calibration of radiographic equipment. These efforts aim to achieve diagnostic imaging that is also safe for patients in accordance with the concept of optimal radiation protection.

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