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IMPACT OF DIGITAL RADIOGRAPHY ON COLLIMATION PRACTICES IN LUMBAR SPINE IMAGING: A COMPARATIVE STUDY OF ANALOGUE AND DIGITAL TECHNIQUES

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Abstract
This study investigates the impact of digital radiography on collimation practices in lumbar spine imaging. A total of 120 frontal radiographs were analyzed to compare collimation accuracy between analogue and digital imaging. Findings indicate that digital radiography resulted in significantly larger irradiated fields, with 63.5 percent of the irradiated area extending beyond the region of diagnostic interest, compared to 45.2 percent in analogue radiographs. The mean irradiated field size increased by approximately 48 percent in digital images. These results suggest a decline in collimation standards following the transition to digital imaging, leading to unnecessary radiation exposure. The study emphasizes the need for improved training in collimation techniques, implementation of standardized protocols, and use of automated collimation systems. Further research is required to assess the broader impact of digital imaging on collimation across different anatomical regions and imaging modalities to ensure patient safety and radiation dose optimization.

Keywords: Digital radiography, Collimation accuracy, Radiation dose optimization, Lumbar spine imaging and Patient safety in radiography.

Introduction
Reducing patient radiation exposure in medical imaging is essential for ensuring safety and maintaining optimal diagnostic standards. To achieve this, appropriate beam limitation is necessary [1]. Restricting the diagnostic target area (DTA) within the irradiated field helps minimize radiation dosage, as a larger irradiated region results in increased exposure [2]. In routine clinical practice, digital image enhancement software can obscure excessive beam restriction, making it challenging to determine whether the image has been properly collimated or digitally altered [3,4]. As a result, maintaining precise beam limitation may be compromised.
As a result, effective beam restriction may be less frequently applied if there is reduced emphasis on its importance. However, it is important to note that this concern has not been extensively investigated in previous research [5,6]. Therefore, the objective of this study is to examine the hypothesis that collimation standards in radiography have declined following the adoption of digital imaging technology.

Materials and Methods

Prior to notifying relevant staff about the study, data collection was completed to prevent any temporary alterations in collimation practices. Ensuring that routine collimation techniques remained unaffected during data gathering was essential for maintaining study reliability.

Sample selection

A total of 120 frontal radiographs were analyzed, with an equal distribution from each category. There were no procedural modifications in lumbar spine radiography during the study period. Radiographs were included if they met the following criteria: they were acquired without fluoroscopic guidance, did not show osteosynthesis materials, and belonged to patients aged 18 years or older. The selection process was conducted by reviewing records over the last four years, beginning with an arbitrary birthdate, until the required sample size was reached.

Collimation assessment

Analog film dimensions were measured using a ruler to evaluate collimation practices. The full extent of the irradiated field, which was not masked in preliminary images or radiography workstations, was analyzed. Physical rulers were employed to measure images displayed on workstation monitors. Due to the reduced screen sizes, additional adjustments were applied when analyzing digital images.

Each analogue and digital image was assessed by calculating the proportion of the irradiated field extending beyond the region of diagnostic interest (RDI). The digital and analog collimation proportions were then compared. The RDI was defined based on existing literature, standard projection protocols, and measurement guidelines. The anatomical boundaries included vertebra S1 cranially, the caudal border of the 12th rib caudally, and vertical lines at the transverse processes laterally. Measurements were taken from the edges of the irradiated field to determine the extent of unnecessary exposure.

All assessments were performed by the same observer to ensure consistency. To evaluate inter-measurement variability, ten analogue and ten digital samples were reanalyzed. The results demonstrated a mean variation of 1.4 percent (maximum 7.8 percent) for analogue images and 2.0 percent (maximum 7.8 percent) for digital images.

To calculate the cranial region outside the RDI, the height of the cranial exposure was divided by the total irradiated height and multiplied by 100. Four digital and eight analogue samples lacked an identifiable RDI, yet they were included in the study for comparison.

The mean irradiated field size was estimated to be 100 square centimeters. For analogue images, this value was directly measured, while for digital samples, adjustments were made due to smaller monitor sizes. To maintain consistency, an equivalent RDI in square centimeters was assumed for both digital and analog images. The scaling factor was determined by dividing the RDI of analogue samples by that of digital samples. Digital images were then adjusted accordingly to estimate their total irradiated field area.

To validate this approach, digital test samples containing an embedded steel ruler were analyzed. A steel ruler with a known 10.0 cm measurement was displayed on the monitor, appearing as 5.2 cm vertically and 4.9 cm horizontally. The RDI on digital monitors was determined using the formula $1/(0.526 \times 0.49)$. Digital samples yielded a mean irradiated area of 751 cm^2, which closely matched the analogue samples' mean area of 773 cm^2. However, due to the restructuring of radiography rooms, acquiring additional test images with a ruler was not feasible.

Data analysis

To compare collimation practices between digital and analogue images, the Mann-Whitney test was employed, as histograms revealed that data distributions were non-normal. Given that patient age can influence collimation, 39 digital and analogue image pairs were matched based on patient age to ensure comparability. Statistical analyses were conducted to determine whether digital imaging has influenced collimation practices.

Results

In the analysis of 120 samples, the irradiated fields were generally larger in digital radiographs compared to analogue images. Across both sides of the irradiated field, the regions of diagnostic interest (RDI) were positioned farther from the outermost boundary of the irradiated field. A statistically significant difference was observed between the proportion of irradiated areas extending beyond the RDI in both digital and analogue samples ($p<0.001$).

The comparison of both groups revealed that the digital imaging group had a higher mean patient age; however, age differences did not significantly impact the extent of the irradiated area beyond the RDI. In digital samples, 63.5 percent of the total irradiated field extended beyond the RDI, whereas in analogue samples, the percentage was significantly lower ($p<0.001$). Among the total study population, the mean irradiated field in digital radiographs was 810 cm², compared to 560 cm² in analogue samples.

Table 1: Digital and Analogue Lumbar Spine Frontal Radiographs - Irradiated Field Outside RDI (Based on 120 Samples)

Parameter	**Analogue (Mean)**	**Digital (Mean)**
Percentage of total irradiated area outside RDI	45.2%	63.5%
Distance from RDI to irradiated edge as a percentage of total irradiated height	16.1%	23.0%
Distance from the edge of the irradiated field to the RDI as a percentage of the total height of the irradiated field	14.5%	20.1%
Left lateral distance between RDI and edge of irradiated field as a percentage of total irradiated width	12.3%	19.2%
Right lateral distance between RDI and edge of irradiated field as a percentage of total irradiated width	11.8%	21.0%

Discussion

Following the transition to digital radiography, a significant increase in the irradiated field size was observed in lumbar spine radiographs, indicating a decline in collimation practices. In this study of 120 samples, radiation exposure to patients increased by approximately 48 percent due to the expanded irradiated field. Since the final processed images in digital radiography can obscure such increases, they may go unnoticed during routine assessments. Given that the lumbar region consists of radiation-sensitive tissues and greater tissue thickness, optimizing collimation is crucial in minimizing unnecessary radiation exposure. While perfect alignment of the irradiated field with the region of diagnostic interest (RDI) is challenging in practice, improving collimation techniques could significantly reduce radiation doses [7-9].

The findings suggest that reverting to more precise collimation methods, similar to those employed in analogue radiography, may help control excessive radiation exposure [10]. To enhance active collimation, it is recommended that radiographers undergo specific training in collimation techniques, adhere to standardized procedures that do not mask the irradiated area, and utilize automated collimators that adjust dynamically when new projections are selected.

These results may also be applicable to lumbar spine radiographs in other healthcare settings, as digitalization has led to similar trends globally. However, it remains unclear whether the observed decline in collimation accuracy is specific to lumbar spine imaging or a more general issue related to digital imaging. Further research is required to assess whether similar trends are evident in other anatomical regions and imaging modalities.

Conclusion

This study of 120 lumbar spine radiographs demonstrates a decline in collimation practices following the transition from analogue to digital radiography. The increase in irradiated field size suggests that patients are exposed to unnecessarily high radiation doses, which could be reduced with improved collimation techniques. Standardized collimation training and technological solutions, such as automated collimators, should be implemented to ensure that collimation accuracy is maintained in digital radiography. Addressing this issue is essential to minimizing unnecessary radiation exposure and improving patient safety in medical imaging.

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