ORIGINAL ARTICLE

Gray Value Variation in Chest Imaging: Effects of Fabric Materials in Computed Radiography.

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Abstract

Introduction: It is generally accepted that patients undergoing chest X-rays may wear their own tops if the clothing is free from metal and is plain. However, there are concerns that such clothing could introduce artifacts, potentially impacting image interpretation. Consequently, it is common practice to require patients to change into provided garments. This study aims to assess the impact of different fabric types on grey-level values in chest radiographs.
Methods: A phantom was positioned against an erect bucky in the posteroanterior position and exposed to X-rays under four conditions: a control setup without any fabric, and three experimental setups involving a radiography examination gown, a cotton t-shirt, and a polyester t-shirt. For each condition, exposure factors were set at 3 mAs and 105 kVp, with three repetitions per condition. The grey values in the processed radiographs were then calculated at seven anatomical points.
Results: The radiographic examination gown consistently showed lower mean grey values at Points 4, 5, 6, and 7, indicating a reduction in mean grey value compared to the control. . These reductions were statistically significant, with the most pronounced change observed at Point 7 (Point 4 = 0.47%, $p = 0.010$; Point 5 = 1.92%, $p = 0.017$; Point 6 = 0.5%, $p = 0.021$; Point 7 = 4.28%, $p = 0.018$).
Conclusion: Hospital gowns can reduce the mean grey values in certain chest areas on radiographs, potentially affecting image interpretation.

Keywords: *artifact, chest X-ray, fabric, gray values, hospital gown, image quality.*

Introduction

In modern medical practice, diagnostic imaging is essential for accurately assessing and managing a wide range of health conditions. X-ray radiography is one of the most commonly used imaging techniques, providing critical insights into the internal structures of the human body. When performing chest X-ray examinations, proper patient preparation is crucial for obtaining high-quality images and ensuring accurate diagnoses. A key aspect of this preparation involves carefully considering the clothing worn by the patient during the procedure.

Several studies have investigated the impact of different fabrics on the quality and safety of X-ray imaging, focusing on various body regions. Research by Choi et al. revealed that both hospital and X-ray department gowns significantly altered the gray levels in digital X-ray images, though they did not introduce artifacts [1]. Similarly, Amran & Mohd Rais (2018) found that heavy, dull satin, high-quality lycra, and moss crepe fabrics did not cause artifacts or significantly affect the image quality of knee radiographs [2]. These findings suggest that certain fabrics may be safely worn during X-ray examinations without compromising the image quality.

However, in the context of chest X-rays, the situation becomes more complex. The low contrast resolution of chest radiographs makes them particularly susceptible to issues caused by artifacts, which can easily be mistaken for abnormalities. Even subtle alterations in gray levels caused by certain fabrics can lead to misinterpretations, potentially resulting in incorrect diagnoses or the need for repeat imaging.

Given the high stakes involved, the prevailing practice is to change the patient's clothing before a chest X-ray as a preventive measure against these risks. Despite evidence suggesting that some fabrics might not introduce artifacts, the potential for misinterpretation due to altered gray levels underscores the importance of this precaution.

Therefore, this study aims to investigate the effects of different fabric materials on gray levels in chest X-rays.

Methods

For the control setup, an N-1 Lungman Multi-Purpose anatomical chest phantom without clothing was positioned against an erect bucky in the Posteroanterior (AP) position with a source-to-image distance (SID) of 180 cm. The X-ray beam was centered at the level of the seventh thoracic vertebrae. The phantom was exposed to X-rays at 3 mAs and various 105 kVp using a Siemens Multix Polydoros IT 55 machines. The exposure was repeated three times.

For the experimental setup, the exposure was made with the phantom wearing a radiography examination gown, a 100% cotton T-shirt, and a 100% polyester T-shirt. All fabrics were plain, free from metal, and wrinkle-free. Other settings were kept constant for both setups.

After exposure, the cassettes were processed using a Carestream DIRECTVIEW Classic CR system reader. The processed radiographs were transferred to a laptop computer for gray value analysis using ImageJ.

For the gray value analysis, seven anatomical points were selected, according to the points used for tuberculosis diagnosis by the Japan Anti-Tuberculosis Association (Figure 1).

The radiographs were zoomed to 300% to ensure accuracy in pinpointing the points. The location of each point for the first radiograph was noted for its y and x coordinates so that the points is constant throughout the study. A selection tool named Rectangular Selection Tools from the software was used to maintain the same size of gray scale evaluation on each point, minimizing the error of measuring the incorrect region of interest (Figure 2). The width and height of the selection tool were kept at 100 for all point measurements of all radiographs to ensure data collection consistency.

The data were analysed using GraphPad Prism 10. A two-way ANOVA with multiple comparisons was used to compare the mean gray values of various fabric materials with the control group at each point. A significance level was set to $p < 0.05$.

Results

A total of 84 images have been acquired in this study. The data, summarized in Table 1 reported the mean grey value when exposing the phantom with the radiography examination gown t-shirt (cotton), and t-shirt (polyester). The control provides the baseline measurements for each anatomical point, ranging from 1,334.20 at Point 1 to 3,500.86 at Point 6.

Radiographic examination gown consistently showed lower mean grey values at Points 4, 5, 6, and 7, indicating a reduction in mean grey value compared to the control. (Figure 3). These mean grey value reductions are significant with the most pronounced at point 7 (Point 4= 0.47%, p-value= 0.010; Point 5= 1.92%, p-value= 0.017; Po int 6= 0.5%, p-value= 0.021 and Point 7= 4.28%, p-value=0.018).

In contrast, other garment conditions, such as T-shirt cotton and T-shirt polyester, did not yield significant differences, with the gray value differences generally closer to zero or positive at other points.

Discussion

This study aims to assess the impact of examination gowns on the quality of radiographic images by comparing the gray values of phantom images obtained with and without various fabrics (radiography examination gown, cotton and polyester t-shirt. In radiological imaging, the "gray value" denotes pixel intensity, which is directly correlated with tissue density as determined by X-ray attenuation [3]. Higher gray values indicate denser tissues such as bone, while lower values correspond to less dense tissues like air or fat.

The generation of gray values in radiological images is influenced by several factors, including X-ray type and energy, tissue characteristics, and imaging device settings such as tube voltage and exposure time [3,4]. The presence of fabric or other materials between the imaging receptor and the tissue being scanned introduces an additional layer of attenuation, affecting the recorded mean gray value [5] . As X-rays traverse the fabric, their energy is partially absorbed or scattered, resulting in lower-energy X-ray photons reaching the detector. The extent of this attenuation is contingent upon the fabric’s material properties, including thickness, density, and composition [6]. Fabrics with higher density, such as heavy cotton or synthetic materials like polyester, exhibit a greater capacity for X-ray absorption.

This study found that hospital gowns significantly reduce mean gray values, whereas other fabrics did not yield a comparable effect. This suggests that hospital gowns possess a higher attenuation coefficient relative to T-shirts made of cotton or polyester. Hospital gowns, typically designed for durability and patient protection, are often constructed from thicker, denser fabrics or multiple layers [7], while T-shirts are generally made from lighter, single-layered fabrics with a looser weave. A similar finding was reported by Ji hoon et al. (2018), who examined the impact of hospital gowns on chest radiographs and concluded that dense fabric gowns may induce minor but measurable changes in image contrast, though these changes were not usually significant enough to compromise diagnostic outcomes. [8] Kusuktham et al. (2016) emphasized that the material composition and thickness are critical factors influencing the extent of X-ray absorption [9].

Radiography examination gowns can cause a reduction in mean gray values, which may have practical implications for diagnostic decisions, particularly in radiographic imaging where contrast and detail are critical. While this reduction may not be perceptible to the human eye if the optical density (OD) changes are below the visual detection threshold, it can still impact the ability to distinguish between different tissue densities or detect subtle abnormalities [10]. Regions corresponding to points 4, 5, 6, and 7 on the chest encompass critical organs, where common pathologies like pulmonary tuberculosis, pleural effusion, and other lung-related abnormalities are often found. Certain pathologies can increase lung tissue density. For example, tuberculosis lesions typically increase tissue density due to granuloma formation and fibrosis, resulting in higher gray values on a radiograph [11,12]. If a thicker radiography examination gown is worn during imaging, the gown's attenuation could lower the mean gray value, potentially obscuring subtle changes in tissue density [13,14]. This is particularly concerning in the early stages of the disease, especially in areas where high contrast and sensitivity are required.

Conclusion

In conclusion, the finding that radiography examination gowns can reduce mean gray values is significant. It indicates that the use of such gowns in radiographic imaging may potentially interfere with the detection and accurate diagnosis of pathologies at critical anatomical points. Therefore, careful consideration of gown material and thickness is essential in clinical settings to ensure that diagnostic accuracy is maintained, particularly when dealing with conditions that alter tissue density.

Conflicts of interest

The authors have no conflict of interest to declare.

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Authors Contribution

NSA and NFI conceptualized and designed the study. NSA collected the data. NFI analysed the data and prepared the manuscript.

Ethical statement

The study does not involve human subjects or their identifiable data. Therefore, it is exempt from the requirement for ethical approval.

Figure 1. The anatomical points used for gray scale evaluation based on Japan Anti-Tuberculosis Association Seven points (Choi et al., 2016). Point 1: The high density area between rib 5 and rib 6 on the right lung; Point 2: The overlapped area of anterior rib 5 and posterior rib 6 on the right of the periphery of lung; Point 3: The transmission part of mediastina carina; Point 4: the area right below mediastina carina; Point 5: The abdominal aortic right at the descending aorta; Point 6: Thoracic vertebrae part 10 and 11 of the shade area of heart; Point 7: The abdominal aortic at the center of right diaphragm.

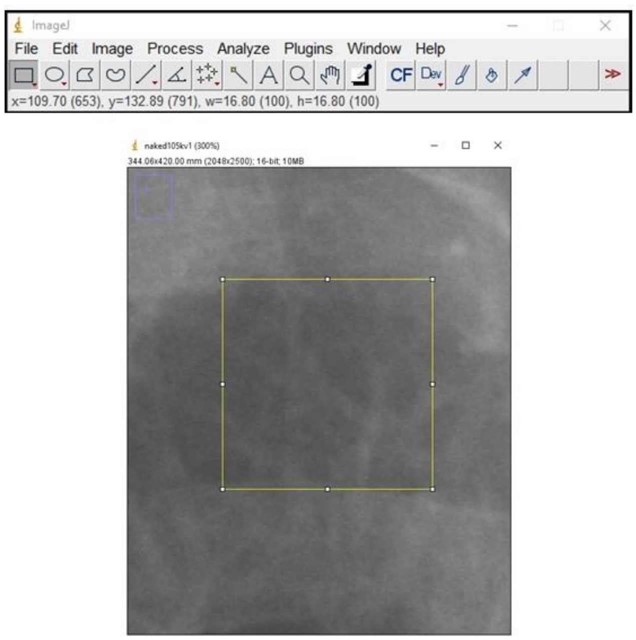

Figure 2. Radiograph was expanded 300% and Rectangular Selection Tool was selected to measure the gray value of each point using ImageJ.

Table 1. Mean gray values at seven points in the chest X-ray after irradiation without fabric (control) and with fabric (radiography examination gown, cotton, and polyester t-shirt).

Anatomical point	Control		Radiography examination gown		T-shirt cotton		T-shirt polyester	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Point 1	1334.20	4.36	1345.17	0.21	1327.07	1.24	1326.74	3.28
Point 2	2237.61	24.08	2286.76	9.98	2236.44	18.68	2242.50	2.47
Point 3	3085.62	4.46	3084.90	1.48	3082.03	2.57	3078.47	1.68
Point 4	3363.45	3.54	* 3347.63	2.75	3363.29	1.06	3360.78	0.70
Point 5	3035.96	14.39	* 2977.61	14.24	3019.12	9.76	3008.66	6.07
Point 6	3500.86	4.88	* 3483.02	4.18	3502.79	1.37	3502.71	1.08
Point 7	2824.25	31.06	* 2703.21	17.85	2827.51	9.33	2825.16	4.90

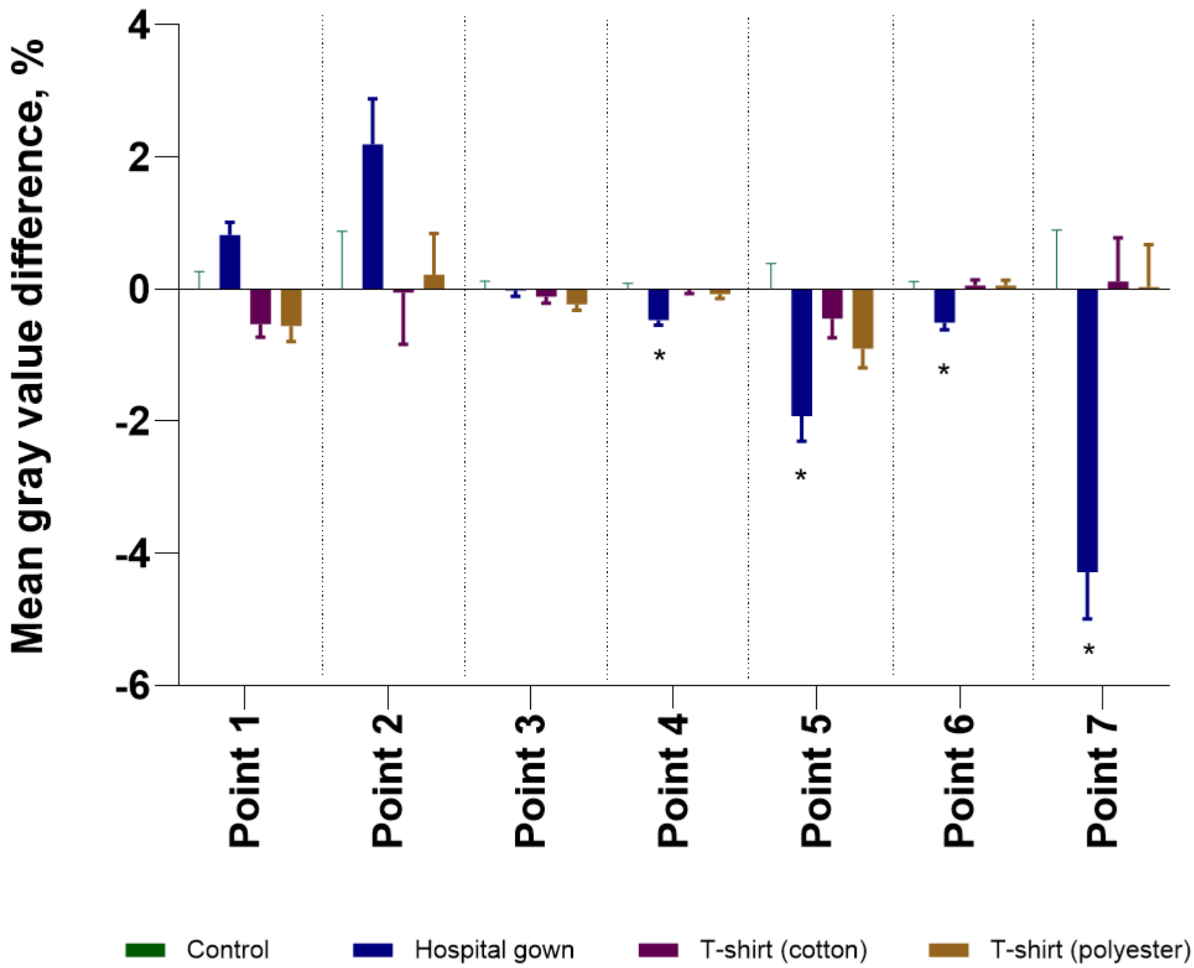

Figure 3. Percentage differences between the mean gray values for the phantom without fabric (control) and with fabric (radiography examination gown, cotton, and polyester t-shirt) at seven points in the chest X-ray.

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