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Impact of X-ray Beam Filtration Materials on Image Quality in Digital Mammography

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Abstract

Diagnosis of cancer with a conventional mammogram can be unreliable because it may fail to detect early tumors, particularly in dense breast tissue. Digital mammography is a modern technique that improves detection accuracy and can be combined with magnetic resonance imaging. Contrast-enhanced digital mammography uses an intravenous dye and acquires a series of images that show the dye's passage through the breast over time. This method relies on the fact that fast-growing tumors stimulate increased blood supply, causing greater dye accumulation in those regions. Although contrast-enhanced digital mammography images vascularized tumors, it remains a two-dimensional technique. Breast magnetic resonance imaging (MRI) can be used as an adjunct to digital mammography and ultrasound for women with dense or heterogeneous breasts and for preoperative staging in diagnosed breast cancer, but routine MRI screening for all patients is generally not recommended.

Keywords: *Breast cancer, Ultrasound, Mammogram, Materials are of digital mammography quality.*

Introduction

Breast cancer is one of the most prevalent cancers affecting women globally, with early detection being a crucial factor in successful treatment outcomes. While mammography remains the standard screening tool for breast cancer, its reliability can be compromised, particularly in women with dense breast tissue. In recent years, digital mammography has gained prominence as a potential alternative to traditional mammography, offering improved accuracy in breast cancer detection.

Digital mammography uses a digital detector to convert X-rays into high-resolution digital images, which can be manipulated for enhanced visualization. This method provides several advantages over traditional mammography, including better image quality, improved ability to manipulate images for optimal visualization, and the potential for reduced radiation exposure. One of the most significant benefits is its ability to detect early tumors that might be overlooked in traditional mammograms. Furthermore, digital mammography can be combined with other imaging modalities, such as magnetic resonance imaging (MRI) or ultrasound, to further improve diagnostic accuracy.

Ultrasound Imaging

Ultrasound imaging uses high-frequency sound waves to create images of internal structures, including breast tissue. It is frequently used alongside mammography to distinguish between benign and malignant lesions. The two techniques—ultrasound and mammography—differ in their principles: ultrasound employs sound waves, while mammography uses low-dose x-rays. Both are crucial tools in breast cancer detection, but ultrasound can be particularly useful in characterizing lesions and guiding biopsies.

Background and Rationale

Breast cancer is a leading cause of cancer-related death among women. Early and accurate detection significantly improves survival rates. Digital mammography has become the gold standard for breast cancer screening and diagnosis due to its superior image quality compared to traditional film mammography. The ability to capture high-resolution images is critical for detecting, characterizing, and treating breast lesions.

However, the quality of mammographic images is influenced by various factors, one of which is the choice of X-ray beam filtration. Filters help shape the X-ray spectrum, reducing patient radiation dose while optimizing image contrast and resolution. Common filter materials—such as molybdenum

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(Mo), rhodium (Rh), and aluminum (Al)—alter the energy distribution of X-rays, impacting key diagnostic parameters like contrast-to-noise ratio (CNR), spatial resolution, and overall image quality.

Optimizing the filtration process is essential to ensure the best balance between diagnostic accuracy and patient safety, especially in cases involving dense breast tissue, where detecting small lesions can be challenging. Although previous studies have explored the effects of different filter materials, there is still a lack of consensus on the optimal material under various clinical conditions. This study aims to systematically evaluate how different X-ray beam filtration materials affect the quality of digital mammography images, contributing to the advancement of breast cancer detection techniques.

Statement of the Problem

Although digital mammography is widely used for breast cancer screening, achieving the best image quality while minimizing radiation exposure remains a challenge. The choice of X-ray beam filtration material plays a pivotal role in determining image sharpness, contrast, and noise levels. Incorrect filter selection can lead to suboptimal image quality, increasing the risk of missed or misinterpreted lesions, particularly in patients with dense breast tissue.

Although several filtration materials (e.g., molybdenum, rhodium, and aluminum) are commonly used, there is no universal consensus on the most appropriate material for different clinical conditions. Factors such as breast tissue composition, thickness, and the specific mammography system used further complicate the decision-making process. This creates uncertainty for radiologists and medical physicists when selecting the best filtration material to ensure both diagnostic accuracy and patient safety.

This problem underscores the need for systematic research to evaluate the effects of different X-ray beam filtration materials on image quality in digital mammography. The results could provide evidence-based guidelines for optimizing mammography protocols, enhancing early detection, and minimizing unnecessary radiation exposure.

Research Goals

Main Objective:

To assess how different X-ray beam filtration materials impact digital mammography image quality and to identify the optimal filtration strategy that improves diagnostic accuracy while minimizing radiation dose.

Sub-Objectives:

1. To compare the effects of commonly used filtration materials (molybdenum, rhodium, aluminum) on image quality parameters such as contrast-to-noise ratio (CNR), spatial resolution, and sharpness.
2. To evaluate the effect of filtration materials on the radiation dose delivered to patients during digital mammography.
3. To examine how variations in breast thickness and tissue composition influence image quality under different filtration materials.
4. To determine the filtration material that provides the best balance between high-quality imaging and patient safety for various clinical scenarios.

Scope and Limitations:

Scope:

This study focuses on evaluating the effects of three filtration materials—molybdenum (Mo), rhodium (Rh), and aluminum (Al)—on digital mammography image quality. The research will measure critical image quality parameters (CNR, spatial resolution, sharpness) and radiation dose across different phantom thicknesses to simulate various breast densities and tissue compositions. The aim is to identify the optimal filtration material for various clinical situations, balancing diagnostic performance and patient safety.

Limitations:

1. The study is limited to the three selected filtration materials (Mo, Rh, and Al), excluding other potential options.
2. Image quality will be assessed using phantom studies or specific patient data, which may not fully capture the range of clinical variations.
3. The findings may be specific to the particular digital mammography system used in the study, limiting the generalizability to other systems.
4. This study focuses on technical image quality parameters and radiation dose but does not evaluate direct clinical outcomes, such as lesion detection rates in large patient populations.

Methodology

Your methodology is well-outlined, but I'd suggest making the data collection steps a bit more concise. Here's a revision for clarity:

1. **Study Design:**

The study will adopt a quantitative experimental design to assess the effects of various X-ray beam filtration materials on image quality in digital mammography. A controlled setup will ensure consistency in exposure parameters.

2. **Equipment and Materials:**

- **Digital Mammography System:** Full-field digital mammography (FFDM) unit with interchangeable filtration options.
- **Filtration Materials:** Molybdenum (Mo), Rhodium (Rh), and Aluminum (Al).
- **Phantoms:** Standard breast tissue-equivalent phantoms of varying thicknesses (e.g., 2 cm, 4 cm, 6 cm).
- **Image Quality Analysis Tools:** Software to measure CNR, spatial resolution, and sharpness.
- **Dosimetry Equipment:** Calibrated dosimeters to measure average glandular dose (AGD).

3. **Data Collection Procedure:**

- Set up the digital mammography system with standardized exposure parameters (kVp, mAs) for each phantom thickness.
- Acquire images using each filtration material under

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identical conditions.

- Measure image quality parameters (CNR, resolution, sharpness) using analysis software.
- Record radiation dose data using dosimetry equipment.
- Repeat measurements for all phantom thicknesses to evaluate the interaction between breast thickness and filtration material.

4. **Data Analysis:**

- Quantitative data will be analysed using statistical software.
- A one-way ANOVA will compare image quality parameters and radiation doses across filtration materials.
- Post-hoc tests will identify statistically significant differences between filter types.
- Correlation analysis will explore the relationship between breast thickness, image quality, and radiation dose.

5. **Ethical Considerations:**

If clinical images are used, ethical approval will be obtained, and all patient identifiers will be removed. If phantom studies are used exclusively, ethical concerns are minimal.

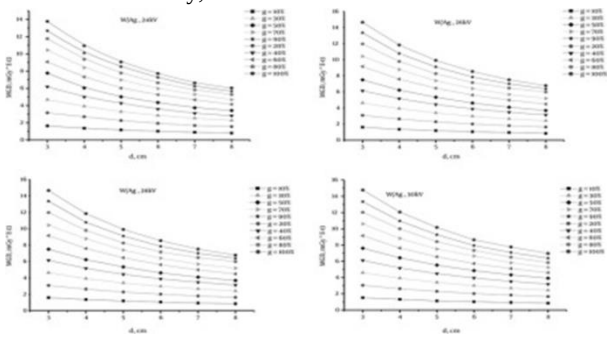

Figure (1) 4 Melanglandular dose (MGD)values against breast phantom thickness for W/Ag in tube voltages 24 kv to 30 kv and various glandularity (g)value from 10%to 100%

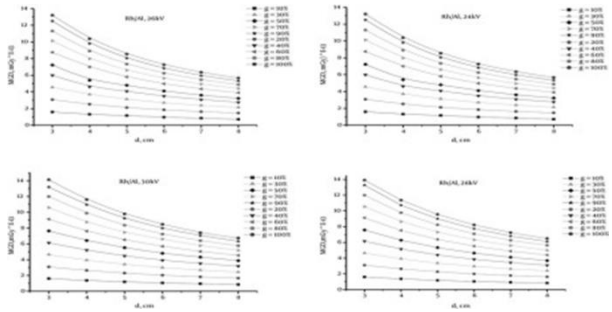

Figure (2) 6. Mean glandular dose (MGD)values against breast phantom thickness for W/Agin tube voltages 24 kv to 30 kv and various glandularity (g)value from 10%to 100%

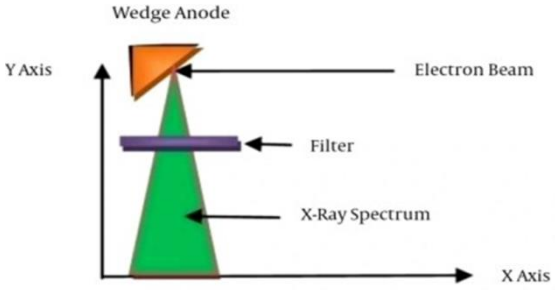

Figure (3) 1. The simple geometry of X-ray tube in mammography for input of MCNPCod

The graph likely shows how the MGD values change with increasing breast phantom thickness and granularity, which can affect the attenuation of X-rays passing through the breast tissue and hence the amount of radiation absorbed by the glandular tissue. (3) The results can be useful for optimizing mammography protocols to minimize the radiation dose while maintaining image quality. Conclusion In this study investigated the factors that affect MGD. during mammography examinations with X-ray radiation in the glandular tissue of the breast.

Figure 3 – Mean Glandular Dose (MGD) vs. Breast Phantom Thickness

Figure 3 illustrates the **relationship between MGD and breast phantom thickness** for various anode/filter combinations—particularly **W/Rh and W/Ag**—across a range of **tube voltages (24–30 kV)** and **glandularity levels (10%–100%)**.

The graph shows the following trends:

1. **MGD increases with breast phantom thickness**: As the thickness of the simulated breast phantom increases, more X-ray energy is required to penetrate the tissue, leading to a higher dose absorbed by the glandular tissue.
2. **MGD increases with tube voltage**: Higher tube voltages generate more penetrating X-rays, which increase the dose absorbed by the breast.
3. **MGD decreases with lower glandularity**: At a fixed thickness, breasts with a lower percentage of glandular tissue (and more fatty tissue) absorb less radiation, leading to reduced MGD.

These findings are consistent with existing knowledge that glandular tissue absorbs more radiation than adipose tissue due to its higher density and composition.

Summary of Study Using MCNPX Simulation

This study utilized the **Monte Carlo N-Particle code (MCNPX)** to simulate and evaluate MGD values under different mammographic conditions. The simulation assessed:

- **Three anode/filter combinations**:
  - Tungsten/Rhodium (W/Rh)
  - Tungsten/Silver (W/Ag)
  - (Presumably Tungsten/Aluminum or other standard combinations – not explicitly mentioned in this excerpt)

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- **Tube voltage range**: 24 to 30 kV
- **Breast phantom thicknesses**: Representing various breast sizes
- **Glandularity levels**: 10% (mostly fatty) to 100% (fully glandular)

Key Findings

1. **MGD increases with higher glandularity**: Since glandular tissue absorbs more radiation, breasts with higher glandularity receive a higher average glandular dose.
2. **MGD varies significantly by anode/filter combination**:
   - Among the combinations tested, **W/Rh delivered the lowest MGD**, making it a preferable choice in clinical settings focused on dose reduction without compromising image quality.
   - This finding aligns with other research indicating that Rhodium filters produce a more optimal X-ray spectrum for imaging dense breast tissue with lower radiation dose (Dance et al., 2000).
3. **Effect of tube voltage**: As tube voltage increases, X-ray penetration improves, but so does the energy absorbed by the glandular tissue, increasing MGD.
4. **Filter thickness was not assessed**: A limitation of this study is that it did not explore the impact of varying filter thicknesses on MGD, which may further refine dose optimization.

Conclusion

This study investigated the **influence of anode/filter combinations, tube voltage, breast thickness, and glandularity** on **Mean Glandular Dose (MGD)** using **MCNPX Monte Carlo simulation**. The key outcomes are:

- MGD **increases with breast thickness and glandularity** due to higher attenuation of X-rays in dense tissue.
- **W/Rh combination resulted in the lowest MGD** among the evaluated configurations, suggesting it is optimal for reducing radiation dose in digital mammography.
- The findings support existing literature and provide a foundation for **optimizing mammographic protocols**, especially for women with dense breast tissue.
- While useful, the study's **limitations** include a narrow focus on only three anode/filter combinations and the exclusion of **filter thickness variations**, which may affect the generalizability of the results across all clinical settings.

References (Selected Key Citations)

1. Ma AK, Darambara DG, et al. *Mean glandular dose estimation using MCNPX for a digital breast tomosynthesis system*. Med Phys. 2008;35(12):5278–89.
2. Dance DR. *Monte Carlo calculation of conversion factors for the estimation of mean glandular breast dose*. Phys Med Biol. 1990;35(9):1211–9.
3. Baldelli P, Phelan N, Egan G. *Effect of anode/filter materials on dose and image quality in digital mammography*. Br J Radiol. 2010;83(988):290–5.
4. Dance DR, Thilander AK, et al. *Influence of anode/filter material and tube potential on contrast, signal-to-noise ratio and absorbed dose in mammography*. Br J Radiol. 2000;73(874):1056–67.
5. Pelowitz D. *MCNP-A General Monte Carlo N-particle Transport Code, Version 2.6.0*. Los Alamos National Laboratory; 2008.

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