The Effect of Age on Mean Glandular Dose and Its Implications in the Detection of Breast Diseases

Walter Manuel Trujillo Yaipen, Magister[1],
[1]Universidad Tecnológica del Perú, Lima, wtrujillo@unprg.edu.pe

Abstract* - Optimizing image quality and minimizing radiation exposure are crucial in mammography. This study identified a significant inverse correlation between patient age and Mean Glandular Dose (MGD), indicating a decrease in glandular density with age. Although statistically significant, the magnitude of this correlation was not as pronounced as expected, suggesting the influence of other factors. Additionally, a strong connection was established between milliampere-seconds (mAs) used and MGD, demonstrating a positive association between radiation quantity and breast glandular density. The correlation between age and MGD was supported by a Pearson coefficient of -0.2745, with strong statistical significance (t-test value = 90.38, p-value = $1.591x10^{-7}$), while the correlation between mAs and MGD was 0.8622 according to the Pearson coefficient, supported by a t-test with a value of 37.82. These findings have significant implications for clinical mammography practice, enabling the adaptation of imaging protocols to each patient's characteristics and reducing the risk of radiation exposure. Furthermore, they suggest the need for future research on optimal radiation levels for different patient groups, which could drive the development of advanced mammography technologies.

***Keywords* - breast glandular density, age, digital mammography, breast disease detection, Pearson correlation.**

I. INTRODUCTION

Early detection of breast diseases is a cornerstone of women's healthcare worldwide. Among the various tools available for this purpose, mammography stands out as an indispensable technique. However, the effectiveness of mammography lies not only in its ability to capture high-quality images but also in the radiation dose to which patients are exposed during the procedure [1]. This crucial point raises a fundamental question guiding this research: how can we improve mammography technique to obtain sharp and accurate images with minimal radiation exposure?

This study focuses on exploring the effect of women's age on the mean glandular dose during mammography and how this impacts the detection of breast diseases. To fully understand this phenomenon, it is essential to consider the theoretical and empirical context supporting this research.

Mammographic density, which reflects the proportion of fibroglandular tissue relative to breast fat, emerges as a determining factor in breast cancer detection. This measure, often evaluated using systems like BI-RADS®, directly influences mammography's accuracy and, consequently, the ability to detect malignant lesions at early stages [2].

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It is important to note that in some U.S. states, legislation now mandates the explicit inclusion of breast density in mammography reports. This underscores the importance the medical community places on breast density in result interpretation and clinical decision-making [3]. However, this regulatory integration has sparked debates due to concerns about potential adverse effects, such as generating unjustified anxiety in patients.

On the other hand, women's age emerges as a critical factor in breast density and, therefore, in mammography's effectiveness as a detection tool. Research has consistently shown an inverse correlation between age and breast density, suggesting that as women age, they tend to have lower breast density [4]. This relationship between age and breast density translates into greater ease in detecting malignant lesions in older women.

Despite technological advances in mammography, such as full-field digital mammography and digital breast tomosynthesis, challenges persist in breast disease detection, especially in women with dense breasts. These women face additional difficulties due to lower mammographic sensitivity, which can result in delays in cancer diagnosis and detection at advanced stages.

Assessment of breast density through the Breast Imaging Reporting and Data System (BI-RADS) significantly impacts mammography sensitivity [11]. It is estimated that around 43% of women aged 40 to 74 have dense breasts, and this proportion tends to decrease with menopause due to involutional changes [7,8].

In addition to its importance in detection, breast density has been identified as a crucial risk factor, accounting for 39% of premenopausal cancer cases and 26% in postmenopausal women [9]. Decreased mammographic sensitivity in dense breasts can negatively affect the detection of non-calcified cancers, potentially leading to diagnostic delays [10,11].

Full-field digital mammography is considered a significant improvement in sensitivity for dense breasts, according to the European Society of Breast Imaging (EUSOBI) [15,16]. However, intermediate criteria need to be evaluated, such as the detection of invasive cancer with negative lymph nodes and interval cancer rates, to measure the effectiveness of supplementary screening in women with dense breasts [1,4,7].

The assessment of breast density has become crucial in the detection and evaluation of the risk of breast diseases, especially in the context of mammography. However, the measurement of breast density can be subjective and variable among observers. To address these limitations, various quantitative tools have been developed, both area-based and volumetric evaluations, aiming to provide objective and reproducible measurements [7].

Quantitative methods, such as Cumulus and deep learning algorithms like Deep-LIBRA, have proven valuable for accurately assessing breast density [15,17]. Additionally, the introduction of volumetric techniques, such as Quantra and Volpara, has improved the ability to predict the risk of breast cancer [18,19].

The impact of breast density on the detection of breast diseases has become more relevant with the routine adoption of digital breast tomosynthesis (DBT). Studies, such as those conducted by the Breast Cancer Screening (BCSC), have evaluated the categorization of BI-RADS density compared to 2D mammograms, either individually or combined with DBT [21,22]. Although no significant changes have been observed in density categorization, the interaction between different mammography modalities, including full-field synthetic mammography, presents additional complexities [23,24].

The clinical implications of breast density extend beyond detection, with laws requiring the communication of density to patients and the inclusion of density measures in risk prediction models [25,26]. Furthermore, analyses of mammographic parenchymal texture, both through traditional methods and deep learning, offer nuanced evaluations that enhance risk stratification and early detection [27].

- DEFINITIONS AND EVALUATION OF BREAST DENSITY

Breast density refers to the proportion of fibroglandular tissue relative to fat present in the breast. This characteristic is evaluated both qualitatively, using classification systems like BI-RADS®, and quantitatively, using techniques that provide objective measurements [28]. Quantitative systems offer precise and reproducible measurements of breast density. For example, planimetry and digitization of mammograms are methods that allow detailed evaluation. Additionally, volumetric assessment, employing techniques such as computed tomography and tomosynthesis, provides a more comprehensive three-dimensional analysis [29].

- SIGNIFICANCE OF BREAST DENSITY

Breast density is considered a moderate risk factor for breast cancer, where higher risk is associated with greater density. However, its relevance in terms of early diagnosis strategies remains a subject of debate.

Breast density can also impact mammography sensitivity by making it difficult to visualize potential cancers, which may justify the use of additional diagnostic modalities in women with dense breasts.

- IMPACT OF AGE ON BREAST DENSITY AND BREAST DISEASE DETECTION

The age of women emerges as a crucial factor in breast density and, therefore, in the effectiveness of mammography as a detection tool. Research has shown an inverse correlation between age and breast density, suggesting that as women age, they tend to have lower breast density [4,7,30]. This finding implies greater ease in detecting malignant lesions in older women.

Despite advancements in mammographic technology, such as full-field digital mammography and digital breast tomosynthesis, challenges persist in detecting breast diseases, especially in women with dense breasts. These women face additional difficulties due to lower mammographic sensitivity, which may result in delays in diagnosing and detecting cancers in advanced stages.

Therefore, it is essential to consider age when interpreting mammograms and designing early breast cancer detection strategies. Understanding how breast density changes with age and how this affects the detection of breast diseases is crucial for improving the effectiveness of mammography as a diagnostic tool in different demographic groups.

II. Material and Methods

A. *Mammography Equipment:*

In this study, a LORAD - HOLOGIC mammography system was used, consisting of an X-ray tube, model M IV, with a 35 kVp Molybdenum (Mo) anode and 39 kVp Rhodium (Rh) anode. Radiation-field-film coincidence tests were performed on the chest wall, and performance was evaluated at 1 m distance under reference conditions.

B. *Calculation of Mean Glandular Dose:*

To determine Performance and Half Value Layer (HVL) in the 25-32 kV range, with 28 kV as reference, for a Mo-Mo anode-filter combination. The equations governing performance behavior and CHR are as follows:

$$\log_{10} R = n \log_{10}(kV) + \log_{10}(A) \quad (1)$$

$$CHR = \alpha(kV)^2 + b(kV) + c \quad (2)$$

Where the values of n, a and b are constants depending on the anode-filter combination and are detailed in Table 1.

Table 1.
Filter Combination, by Material

Combination Anode/Filter	Filter Thickness	n	a	b
Mo/30μm Mo	36.1 μm	3.06	-0.000326	0.0273

Note, *Robson Table. (*SEFM*)*

Given the Performance, the Kerma in Air at the Entrance Surface (KASE) of the breast can be estimated [31].

$$\text{KASE} = \text{R(mGy/mAs).C(mAs)}\left[\frac{dr}{SID-(PID-Bt)}\right]^2 \quad (3)$$

Where:

- R: Performance at 1 meter corresponding to the anode-filter combination used.
- C: applied load.
- D: measured distance from source to exposure point of measured performance.
- SID: measured distance from source to image receptor.
- PID: distance from the support plane of the patient's breast to the image receptor plane.
- Bt: compressed breast thickness.

C. Dance Method:

According to the method initially proposed by Dance (1990), the mean glandular dose was calculated using the equation: [4,31]

$$\text{DGM(mGy)=KASE(mGy). g} \quad (4)$$

The factor "g" is calculated for a Mo-Mo anode-filter combination and for a breast combination of 50% glandularity and 50% adipose tissue.

However, g varies depending on the anode-filter combination used and also depending on the % of glandular tissue in the breast. Therefore, Dance et al. propose the following equation for obtaining the "Mean Glandular Dose": [4,31]

$$\text{DGM(mGy)=KASE(mGy).g.s.c} \quad (5)$$

Where:

- g = f (CHR, breast thickness)
- s = f (anode-filter combination)
- c = f (glandularity %, breast thickness, CHR, Age Group {40-49 or 50-64})

It is important to mention that the method proposed by Robson and the Dance tables are used as a reference to estimate the percentage of glandular tissue in the breast. These tables provide average values and consider factors such as age and breast thickness for estimation.

D. Patient Selection:

In studies related to mammography and breast glandular density, patient selection may involve specific criteria to ensure representativeness and validity of results.

Some factors considered in patient selection may include:

- Population: The study population consists of 360 patients who underwent mammography.
- Sample: A sample of 114 patients who underwent craniocaudal mammographic projections was extracted.
- Age: Age is an essential component in the analysis of breast glandular density, as a correlation between breast density and the risk of breast diseases such as breast cancer has been established. Therefore, the study may have limited patient selection to a specific age range to evaluate the connection between age and breast glandular density.
- Medical history: The medical history of patients is relevant as a criterion in study selection. For example, patients with a history of previous breast surgery or specific breast-related treatments that could affect glandular density may have been excluded.
- Health status: The general health condition of patients may have been considered, excluding those with known breast conditions, such as benign or malignant breast diseases.
- Family history: The presence of family history of breast diseases, such as breast cancer, may also have been a criterion in patient selection. Studies often seek to evaluate risk factors and genetic associations, so patients with a family history may be selected for this purpose.

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III. RESULTS:

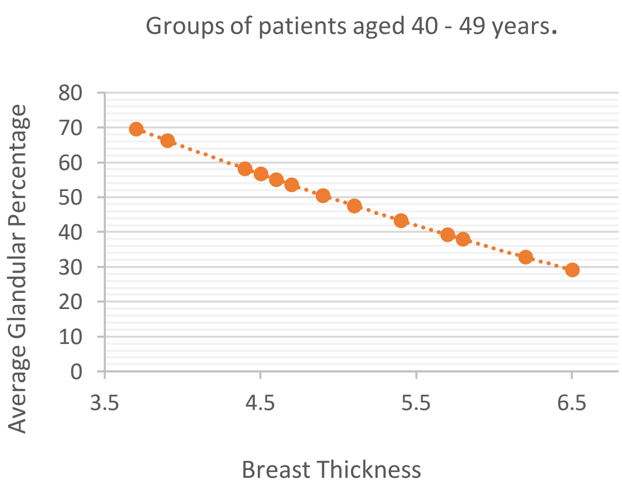
Early detection of breast diseases, especially breast cancer, is crucial for improving survival rates and effective treatment. One of the key factors influencing accurate detection of these diseases is the patient's age, as well as breast tissue thickness and composition. In this study, we focused on analyzing the effect of age on the mean glandular dose (DGM) and its relationship with the detection of breast diseases through mammography.

To better understand this effect, we relied on the approach proposed by Dance, which considers both density and thickness of breast tissue. Our results revealed significant differences in DGM between two groups of patients: those aged 40-49 years and those aged 50-64 years, as shown in figure 1 [31].

In the first group of patients, we observed a gradual decrease in the average glandular percentage as breast thickness increased. This phenomenon can be explained by the need for more radiation to penetrate thicker tissues, resulting in greater radiation attenuation and consequently, a decrease in glandular percentage.

Furthermore, thicker breasts tend to have a lower proportion of glandular tissue and a higher proportion of fatty tissue, further contributing to the decrease in glandular percentage [31].

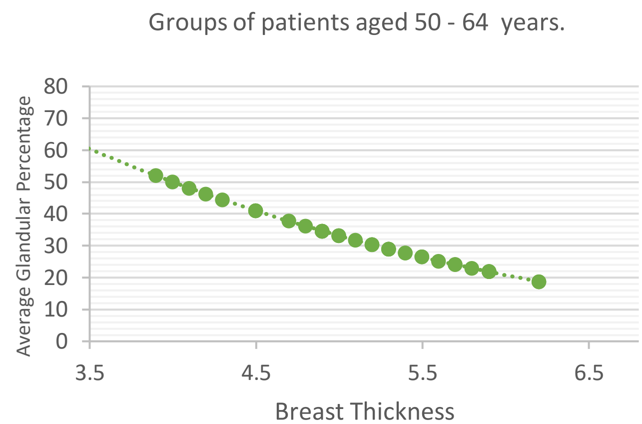
Figure 1
Average Glandular Percentage vs. Breast Thickness



In contrast, in the group of patients aged 50-64 years (see figure 2), we observed a more rapid decrease in the average glandular percentage as breast thickness increased. Additionally, we noted an increase in breast density measured by KASE as breast thickness decreased in this group.

These findings are particularly relevant as breast glandular density can significantly influence the early detection of breast pathologies, especially in older women.

Figure.2.
Average Glandular Percentage vs. Breast Thickness



Comparing the two groups of patients, we found that the decrease in the average glandular percentage in the 50-64 age group was more pronounced than in the 40-49 age group. This suggests that breast density decreases with age, resulting in a relatively higher proportion of fatty tissue and a lower proportion of glandular tissue.

These findings underscore the importance of considering age and tissue composition when interpreting mammograms for accurate detection of breast diseases, especially in older women.

Proper selection of radiographic parameters is essential to achieve an optimal balance between image quality and radiation dose. The choice of kVp (peak kilovoltage) and mAs (milliampere-seconds) plays a crucial role in this process. Increasing the kVp allows better radiation penetration through breast tissue, which may result in a clearer and more detailed image. However, excessive kVp can lead to radiation overexposure [1,4].

On the other hand, mAs determines the amount of radiation used during image acquisition. Properly adjusting the mAs allows obtaining an optimal radiation dose without compromising image quality. It is essential to find the right balance, as excessive mAs can result in unnecessarily high radiation dose for the patient.

Optimizing image quality and minimizing radiation exposure are fundamental aspects of performing mammograms. The results obtained in this study highlight the importance of considering tissue composition, breast thickness, and patient age when interpreting mammographic images and detecting potential pathologies. Additionally, careful selection of radiographic parameters, such as kVp and mAs, is crucial for obtaining high-quality images with an appropriate radiation dose [1]. These findings contribute to improving the effectiveness and safety of early detection of breast cancer in women with different breast densities.

This table provides essential demographic and statistical insights derived from the study's dataset. In the "Data" column, we observe the mean age of the participants, which stands at 52.30 years. This average age serves as a central indicator of the age distribution within the sample population, representing the typical age of individuals undergoing mammographic screening.

Furthermore, the variance of the Mean Glandular Dose (DGM) is depicted as 33.08. This variance value illustrates the extent of dispersion or spread of DGM values observed among the study participants. A higher variance suggests greater variability in DGM values, indicating that the sample encompasses a diverse range of glandular densities among the participants.

Additionally, the correlation coefficient between age and DGM is presented as -0.2745. This correlation coefficient quantifies the strength and direction of the relationship between age and DGM. A negative value suggests an inverse relationship, meaning that as age increases, DGM tends to decrease. However, the magnitude of -0.2745 indicates a weak correlation, implying that while there is a discernible trend, it is not particularly strong.

Table 2:
Summary of Demographic and Statistical Data

	Age (Mean)	DGM (Variance)
Data	52.30 años	33.08
Correlation	-0.2745	
t-Test	90.38	1.591×10^{-7}

Note: The table provides a summary of key demographic and statistical characteristics, highlighting the inverse relationship between age and DGM.

In Table 3, which displays the correlation between the key variables of interest in our study, significant patterns are revealed. For instance, when examining the relationship between age and mammographic density (MD), we find a Pearson coefficient of -0.2745. This value indicates a weakly negative correlation, suggesting that as age increases, mammographic density tends to decrease slightly, although this association is not very strong.

On the other hand, the correlation between the amount of radiation used, measured in milliampere-seconds (mAs), and mammographic density is notably more robust. Here, the Pearson coefficient is 0.8622, signaling a strong positive correlation. This implies that as the amount of radiation administered during mammography increases, mammographic density tends to increase considerably.

This analysis suggests that the amount of radiation employed during the mammography procedure has a significant influence on the observed mammographic density. It is important to note that while age appears to have a modest influence on mammographic density, the amount of radiation used emerges as a more substantial determinant. These findings could have important implications for optimizing mammographic imaging protocols and understanding the factors influencing mammographic density in the studied population.

Table 3:
Correlation between Variables

	Age– DGM	mAs -DGM
Pearson Coefficient	-0.2745	0.8622

Note: This table highlights the correlation between variables, indicating the inverse relationship between age and DGM, and the positive relationship between mAs and DGM.

Table 4 presents the comprehensive results derived from the application of the t-test, a fundamental statistical tool utilized to ascertain the significance of differences between the means of two related samples. Specifically, the focus lies on evaluating the relationship between age and mammographic density (DGM), as well as the association between the quantity of radiation administered (mAs) and DGM.

Within this table, meticulous attention is given to each variable under examination. The mean, which represents the average value of each dataset, is provided alongside the variance, offering insights into the dispersion or spread of data points around the mean. Additionally, the count of observations denotes the number of paired samples considered for analysis, contributing to the robustness and reliability of the findings.

Of notable importance are the t-statistic values associated with each relationship. These values serve as indicators of the extent to which the observed differences in means are likely to be attributed to true differences in the populations from which the samples were drawn, rather than random chance. The remarkably high t-statistic values observed for both age-DGM and mAs-DGM relationships underscore a profound statistical significance, signifying that the observed differences in means are unlikely to have occurred by mere coincidence.

In essence, the findings presented in Table 4 underscore the substantive statistical significance of the correlations between age and DGM, as well as between the amount of radiation used (mAs) and DGM. This robust validation lends credence to the reliability and validity of the associations uncovered, thereby informing further understanding and interpretation within the context of the study's objectives.

Table 4:
Paired Samples t-Test for Means

	Age –DGM	mAs - DGM
Mean	52.30	130.66
Variance	33.08	1358.20
Observations	114	114
Pearson Coefficient	-0.2745	0.8622
t-Statistic	90.38	37.82

Nota: La prueba t confirma la significancia estadística en las relaciones entre Edad-DGM y mAs-DGM, respaldando los resultados de las correlaciones.

CONCLUSIONS

The optimization of image quality and the minimization of radiation exposure are crucial aspects in performing mammograms, and the results obtained in this study reinforce this premise. Careful consideration of tissue composition, breast thickness, and patient age when interpreting mammographic images is fundamental for effectively and safely detecting potential pathologies. Additionally, precise selection of radiographic parameters such as kVp and mAs is essential for obtaining high-quality images with an appropriate radiation dose.

The findings of this research, which involved 360 patients with a particular focus on 114 women, provide valuable information on the relationship between age, milliampere-seconds (mAs), and Mean Glandular Dose (MGD) in mammography. A significant inverse correlation was found between age and MGD, suggesting a decrease in breast glandular density as women age.

Specifically, the average age was 52.30 years, with a variance of 33.08. The correlation found between age and MGD was supported by a Pearson coefficient of -0.2745, with a t-test showing a value of 90.38 and a p-value of 1.591×10^{-7}, indicating a strong statistical significance. However, it is important to note that although the correlation was statistically significant, its magnitude was not as pronounced as expected to be considered strongly negative. This finding suggests that while age influences breast density and hence MGD, other factors are likely at play as well.

Furthermore, a robust connection was established between the mAs used and MGD, highlighting the importance of considering radiation dose when performing mammograms. The average mAs was 130.66, with a variance of 1358.20. The correlation between mAs and MGD was 0.8622 according to the Pearson coefficient, supported by a t-test with a value of 37.82.

The research also revealed a positive association between the amount of radiation used (mAs) and MGD, suggesting that an increase in radiation leads to an increase in breast glandular density. This understanding is crucial for properly adjusting radiographic parameters and ensuring a safe and effective radiation dose for each patient.

These findings have significant implications for clinical practice in mammography. Physicians can use this information to tailor imaging protocols to the specific characteristics of each patient, thereby improving diagnostic accuracy and reducing the risk of unnecessary radiation exposure.

Additionally, these results pave the way for future research that could explore optimal radiation levels for different patient groups, potentially leading to the development of advanced mammography technologies that improve the detection of breast diseases and reduce radiation exposure.

Ethical responsibilities:

- **Protection of humans and animals**
  The authors declare that no experiments have been conducted on humans or animals for this research.

- **Data confidentiality**
  The authors declare that they have followed their institution's protocols regarding the publication of patient data.

- **Right to privacy and informed consent**
  The authors declare that no patient data appears in this article.

- **Conflict of interests**
  The lead author and collaborators declare no conflicts of interest in the present study.

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