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Evaluation of the relationship between digital mammography radiation dose and patient age, breast volume and density

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ABSTRACT

Aims: To determine the average radiation dose values in patients who underwent routine screening mammography in our hospital, establish the relationship between breast density and volume, and investigate other factors affecting radiation dose.

Methods: Screening bilateral mammography was retrospectively evaluated within the specified period of 2 months. Patient age, breast density ratio, mammographic size of the breast, calculated breast volume, tube voltage, current, exposure time (ms), compression force (kg), compression thickness (mm), and radiation dose (mGy) given in each projection were recorded separately for each patient. According to the BI-RADS, breast densities classified as types A-B were considered non-dense, while types C-D were considered dense breasts. The 75th percentile dose value (mGy) was chosen as the cutoff for high dose group. Logistic regression analyses were used to examine the factors affecting radiation dose.

Results: 1720 mammograms from 430 patients were studied. 276 (64.2%) breasts were non-dense, while 154 (35.8%) breasts were dense. The mean total breast volume was 595±334 ml, compression thickness was 36.5±12.0 mm, and radiation dose was 2.04±0.75 mGy. There was a negative correlation between radiation dose and age ($r=-0.330$, $p<0.001$), while a positive correlation was found between radiation dose and breast volume ($r=0.514$, $p<0.001$), kV ($r=0.608$, $p<0.001$), mAs ($r=0.912$, $p<0.001$), exposure time ($r=0.820$, $p<0.001$), compression thickness ($r=0.629$, $p<0.001$) and strength ($r=0.084$, $p<0.001$). In the regression analysis conducted excluding technical parameters, age, breast volume, density, and compression thickness all influence radiation dose, with compression thickness having the greatest effect, followed by breast volume, age, and finally breast density.

Conclusion: The most important factors influencing radiation dose are technical parameters such as tube voltage, current and exposure time. However, apart from technical parameters, compressed breast thickness is the most affecting factor, followed by breast volume, age, and least of all, breast density, in affecting radiation dose.

Keywords: Mammography, breast, radiation dosage, diagnostic imaging, breast density, diagnostic screening programs

INTRODUCTION

Breast cancer is the most common cancer in women, both in Turkey and worldwide.[1,2] The mortality rate in patients with breast cancer can reach up to 30.7%, accounting for 11.6% of total cancer deaths.[3-5] Furthermore, it is stated that a woman has a 12% risk of developing breast cancer throughout her lifetime.[5,6] Due to its high prevalence and mortality rates, early diagnosis of breast cancer is crucial. For this purpose, screening programs for breast cancer have been developed in many developed countries for women aged 40 and above. These programs aim to detect the disease at an early stage and reduce mortality and morbidity. There are studies that demonstrate a decrease in mortality from breast cancer through these screening programs.[7]

Mammography is the most commonly used imaging technique for breast cancer screening due to its low cost, accessibility, ease of application, and high sensitivity.[8] In most mammography procedures, two different projections, craniocaudal (CC) and mediolateral oblique (MLO), are routinely performed for each breast. This method is based on the use of ionizing radiation for imaging. The use of imaging techniques that involve ionizing radiation is becoming increasingly widespread. This situation has raised concerns about the risk of radiation exposure.[9,10] While the radiosensitivity of each tissue varies, it is known that radiation exposure increases the incidence of many cancers.[11] The radiation weighting factor for the breast has been determined to be 0.12. It is known to be a radiosensitive tissue, and it represents

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12% of the total radiation damage that occurs in the case of homogeneous radiation exposure throughout the body.[12] In breast cancer screening programs, radiation exposure to each breast in two different projections every year after the age of 40 raises concerns about radiation exposure in some women in the screening age group and causes avoidance of screening mammography.[13,14] However, it has been reported in the literature that screening mammography alone has led to a decrease in breast cancer-related mortality in the United States, and the benefit obtained from early detection of breast cancer outweighs the risk of breast cancer associated with radiation exposure.[15,16]

Understanding the factors that affect radiation exposure to the breast and the radiation dose in mammography used in routine screening programs is important for controlling radiation dose. The radiation dose absorbed by the breast can vary widely depending on various factors. There are studies in the literature that examine mammography doses and the influencing factors. These studies have indicated a positive correlation between breast compression thickness, body mass index, and breast radiation dose. Although studies on the relationship between breast density and dose are limited, there are studies indicating higher dose exposure in dense breasts. In order to generate high-quality images in denser breasts, it may be necessary to use more X-rays, which can result in higher radiation exposure.[5] Additionally, it is stated that women with denser and larger breasts may have a higher radiogenic risk.[5]

To assess a patient's radiation-induced exposure, the average glandular dose (AGD) is evaluated and expressed in mGy (milligray). AGD represents the dose received by the compressed tissue of the breast. Compression is applied to reduce the thickness and radiation exposure of the breast. The volume of the breast is obtained by measuring the breast dimensions in two planes and calculating it with compression thickness. It has been reported that young women with denser and larger breasts are at a higher risk for radiation-induced secondary breast cancer due to higher radiation exposure. In the literature, it has been reported that the average reported dose per mammography image ranges from 1.1 to 2.2 mGy, while it varies between 2.0 and 5.4 mGy for each breast.[5,17-19] In radiation protection, the fundamental principles used to minimize the risk of radiation exposure are correct justification, dose optimization, and dose limitation methods.[17,20,21] Therefore, it is recommended to keep the dose applied to the breast during mammography as low as reasonably achievable (ALARA) without compromising image quality. The assessment of mammography doses and the investigation of factors affecting radiation dose are crucial for evaluating the procedure and ensuring compliance with national and international diagnostic reference levels.

The aim of this study is to determine the average radiation dose values in patients who underwent routine screening mammography in our hospital, establish the relationship between breast density and volume, and investigate other factors affecting radiation dose. In this way, it is also aimed to raise awareness about radiation exposure and to emphasize dose control.

METHODS

The study was designed retrospectively and was approved by the ethics committee of our hospital (Date:05/07/2023, Decision No:2023-KAEK-79). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

Study Population

The retrospective evaluation of bilateral mammography examinations performed for screening was conducted at our hospital's mammography unit using a single device (Giotto IMS, Bologna, Italy).

The inclusion criteria were determined as follows: being 40 years of age or older, being female, having a Breast Imaging Reporting and Data Systems (BI-RADS) assessment result of category 1 or 2 (negative or benign findings), and having adequate quality images in bilateral craniocaudal (CC) and mediolateral oblique (MLO) projections.

The exclusion criteria for the study included a history of mastectomy, breast-conserving surgery, or radiotherapy treatment, BI-RADS assessment categories of 3, 4, 5, or 6, being a male patient, having breast implants, missing one of the bilateral CC and MLO projections, or having other types of mammography images such as spot compression or magnification.

In the determined two-month period, 120 images of 30 patients due to BI-RADS 3,4,5, 44 images of 22 patients due to previous mastectomy, 2 images of 2 patients due to only one projection and on a single breast, a total of 54 patients 166 images were excluded from the study. These patients were not included in the study.

Consequently, a total of 1720 mammography images from 430 patients were included in the study.

Data Collection

The images were retrospectively reviewed using the same model workstation (Giotto IMS, Bologna, Italy) as the mammography device. Patient age, breast density ratio according to American College of Radiology (ACR) breast imaging-reporting and data system (BI-RADS), mammographic size of the breast, kV, mA, exposure time (ms), compression force (kg), compression thickness (mm), and radiation dose (mGy) given in each projection were recorded separately for each patient.

The density of the breast according to ACR BI-RADS was evaluated in four categories. The breast density was classified as follows: 0-25%: category A, 25-50%: category B, 50-75%: category C, and 75-100%: category D. The images were visually evaluated by a radiologist with 10 years of experience, and a consensus was reached by comparing the density result determined according to ACR BI-RADS in the patient's previous report written in the Hospital Information System. The final decision was made by a 10-year-experienced radiologist who evaluated the images, taking into account the report in the hospital system. Breast densities classified as types A-B were considered non-dense, while types C-D were considered dense breasts.

Mammographic breast size measurements were performed on the workstation by measuring the anterior-posterior (AP) and mediolateral (ML) dimensions of the breast in the CC projection. In conjunction with breast compression thickness, the formula (π/4 × AP measurement × ML measurement × compression thickness), as described by Kalbhen et al.[22] was used to calculate breast volume.[23] For MLO images, the AP and CC dimensions of the breast were measured, and using the same formula, the total volume of the breast and axilla was calculated. The measurement procedure is shown in **Figure 1**.

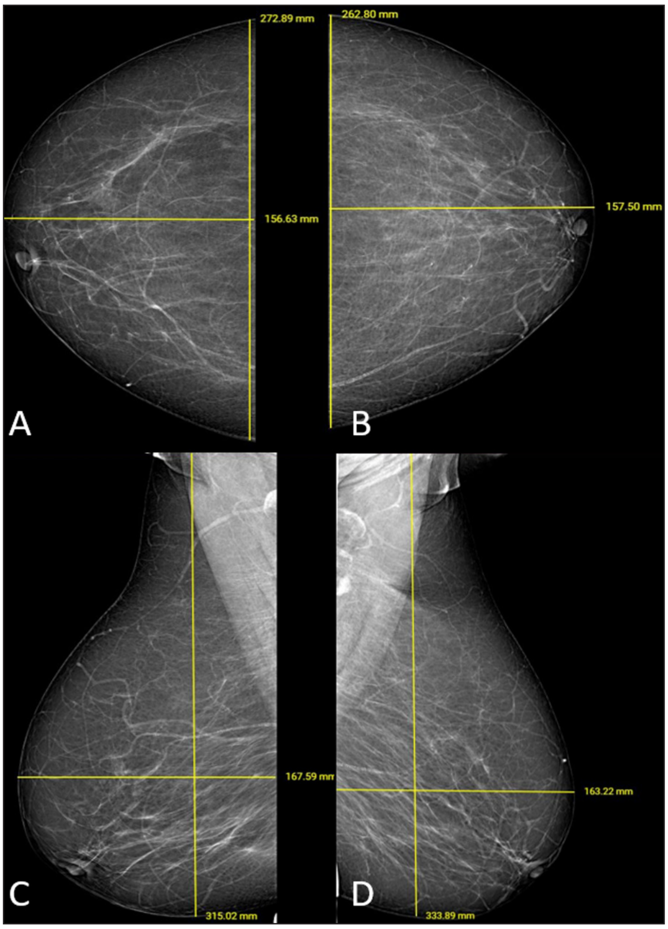

Figure 1. Breast measurements. A, B. Measurement of anteroposterior and mediolateral diameters in craniocaudal (CC) images, C, D. Measurement of anteroposterior and craniocaudal diameters in mediolateraloblic (MLO) images.

The radiation dose exposure mentioned in the study represents the total radiation exposure dose calculated by the mammography unit in the specified workstation for both CC and MLO images. The safe limit for a single projection mammogram, as stated by both the Food and Drug Administration (FDA) and the International Commission on Radiological Protection (ICRP), is 3 mGy in terms of Mean Glandular Dose (MGD).[12] Additionally, some diagnostic reference level studies utilize the 75th and 95th percentile values. In this study, the 75th percentile value was chosen as the cutoff for high dose, classifying images with doses higher than the 75th percentile as high dose, and those with lower doses as low dose.

Statistical Analysis

For all analyses, IBM SPSS 26.0 (NY, USA) statistical software was used. Descriptive statistics were presented as mean±standard deviation for numerical data, and counts and percentages for categorical data. The normality of the data was assessed using the Kolmogorov-Smirnov test, and it was determined that none of the variables followed a normal distribution. Therefore, nonparametric tests such as Mann-Whitney U test for group comparisons and Spearman correlation analysis for correlation analyses were used. Logistic regression analyses were used to examine the factors influencing radiation dose, including patient age, breast density, and compression thickness, both with and without the technical parameters associated with the device. The results of the regression analysis were presented with odds ratios and 95% confidence intervals. A p-value of <0.05 was considered statistically significant.

RESULTS

A total of 430 patients' mammography images, comprising 1720 images in total, were included in the study. These images consisted of an equal number (n=430) of right and left breasts, including both CC and MLO views. The mean age of the patients was 54.6±10.7 years. According to the ACR BI-RADS breast density categories, 126 (29.3%) breasts were classified as type A, 150 (34.9%) as type B, 114 (26.5%) as type C, and 40 (9.3%) as type D. When type A-B breasts were considered as non-dense and type C-D breasts were considered as dense, 276 (64.2%) breasts were classified as non-dense, while 154 (35.8%) breasts were classified as dense (**Table 1**).

The mean total breast volume was 595±334 ml, with the right breast having an average volume of 586±334 ml and the left breast having an average volume of 603±344 ml. When including the axillae in the MLO view, the mean volume for both sides was calculated as 899±488 ml, with the right side calculated 877±489 ml and the left side calculated 921±499 ml (**Table 2**).

Table 1. Breast densities of patients according to ACR BI-RADS classification		
BI-RADS density	**N**	**%**
Non-dense	276	64.2%
Type A breast	126	29.3%
Type B breast	150	34.9%
Dense	154	35.8%
Type C breast	114	26.5%
Type D breast	40	9.3%
Total	430	100%

Table 2. Breast volume measurements results from CC and MLO projections on the right and left breast			
Volume measurements (ml)	**N**	**Mean**	**Standart Deviation**
Right breast volume (CC)	430	586	334
Left breast volume (CC)	430	603	344
Average breast volume (CC)	860	595	334
Right breast and axilla volume (MLO)	430	877	489
Left breast and axilla volume (MLO)	430	921	499
Average breast and axilla volume (MLO)	860	899	488

CC: Craniocaudal, MLO: Mediolateraloblique

The mean compression thickness was 36.5±12.0 mm, the mean kV value was 27.1±1.6 kV, the mean mAs value was 94.8±29.5 mAs, the mean exposure time was 697±212 ms, the mean compression force was 14.8±3.1 kg, and the mean radiation dose was 2.04±0.75 mGy (Table 3). The distribution of these measurements in the right and left breast CC and MLO projections is shown in Table 3.

In the comparison made between the dense and nondense breast groups based on breast density, statistically significant differences were found in radiation dose for each projection, total radiation dose and all mammography technical parameters ($p<0.05$) (Table 4).

According to the results of the correlation analysis, there was a negative correlation between radiation dose and age, while a positive correlation was found between breast volume, kV, mAs, exposure time, compression thickness and strength (Table 5, Figure 2).

Due to the data not suitable a normal distribution, univariate and multivariate logistic regression analyses could not be performed. Using the cut off value of 2.6 mGy obtained from the 75th percentile in our study, all images

Table 3. Distribution of the obtained data values in the right and left breast CC and MLO projections					
	Right CC (Mean±SD)	**Left CC (Mean±SD)**	**Right MLO (Mean±SD)**	**Left MLO (Mean±SD)**	**Total (Mean±SD)**
AP Mesaurements (mm)	101.0±26.5	102.9±26.6	109.8±26.5	110.1±26.4	106.0±26.8
ML Measurements (mm)	204.4±25.3	206.6±27.3	244.8±24.5	246.9±24.2	225.7±32.4
Compression Thickness (mm)	33.6±10.9	33.5±11.2	38.7±11.9	40.3±12.4	36.5±12.0
Breast Volume (ml)	586±334	603±344	877±488	921±499	747±450
Voltage (kV)	26.7±1.3	26.7±1.4	27.4±1.6	27.6±1.7	27.1±1.6
Tube Current (mAs)	87.6±27.3	90.1±27.3	102.2±29.2	99.4±31.5	94.8±29.5
Exposure Time (ms)	657±209	669±203	744±207	717±216	697±211
Compression Pressure (kg)	14.7±3.0	15.0±3.1	14.9±3.0	14.7±3.3	14.8±3.1
Radiation Dose (mGy)	1.84±0.65	1.87±0.63	2.24±0.76	2.23±0.87	2.04±0.76

CC: Craniocaudal, MLO: Mediolateraloblique, AP: Anterioposterior, ML: Mediolateral, SD: Standart Deviation

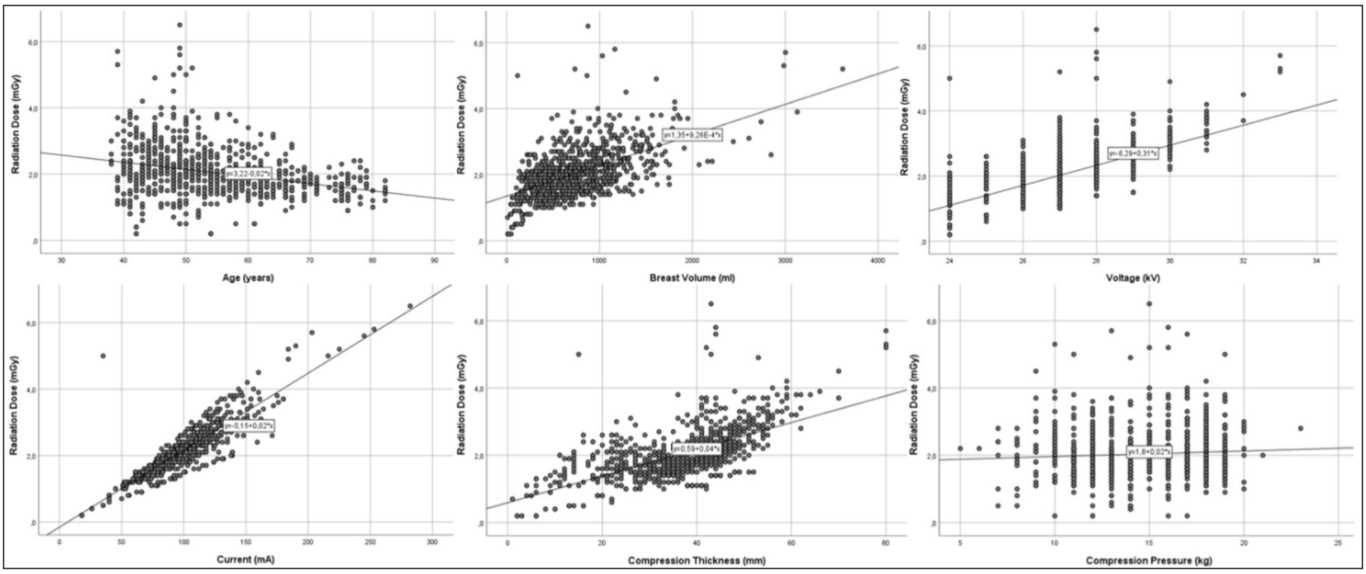

Figure 2. Correlation graphs between radiation dose (mGy) and age, breast volume, voltage, current, compression thickness and compression pressure, respectively. There is a negative correlation between age and radiation dose, and a positive correlation is observed in other graphs. It is seen in the graph that there is a weak positive correlation between the compression pressure and the radiation dose.

were divided into two groups: high dose (≥2.6 mGy) and low dose (<2.6 mGy) exposures. Thus, binary logistic regression analysis was conducted. The comparison of the values between the high dose and low dose groups is shown in Table 6, and the results of the regression analysis are shown in Table 7. In the initial regression analysis, technical parameters related to the automatic exposure of the device, such as mA, kV, exposure time, and compression force, were included. In the second analysis, only age, breast density, and compression thickness were included, excluding these technical parameters (Table 7). According to the results of the regression analysis, among the technical parameters, tube voltage has the most significant impact on increasing radiation dose, followed by tube current. Exposure time contributes to a lesser extent to the increase in radiation dose. Compression pressure, on the other hand, did not have an effect on radiation dose in our study. In the regression analysis conducted excluding technical parameters, age, breast volume, compression thickness, and breast density all affect radiation dose, with compression thickness having the greatest effect, followed by breast volume, age, and finally breast density (Table 7).

Table 4. Comparison of radiation dose measurements and technical parameters in dense and non-dense breast groups

	N	Non-Dense Breast (Mean±SD) (n=1104)	Dense Breast (Mean±SD) (n=616)	P Value
Voltage (kV)	1720	27.4±1.5	26.5±1.5	<0.001
Tube Current (mAs)	1720	90.5±21.2	102.4±39.2	<0.001
Exposure Time (ms)	1720	658±136	766±291	<0.001
Breast Volume (ml)	1720	864±467	537±325	<0.001
Age (years)	430	58.7±10.6	47.2±5.6	<0.001
Compression Thickness (mm)	1720	39.0±11.1	32.2±12.3	<0.001
Compression Pressure (kg)	1720	14.9±3.1	14.6±3.0	0.015
Radiation Dose (mGy) (for each projection)	1720	2.00±0.64	2.12±0.93	0.001
Total Radiation Dose (mGy)	430	7.99±2.14	8.48±3.12	0.028

*Mann-Whitney U test, SD: Standart Deviation

Table 5. Correlation analyzes between radiation dose with age and mammographic parameters

	Non-Dense (n=1104)		Dense (n=616)		Total (n=1720)	
	r	p	r	p	r	p
Age/dose*	-0.449	<0.001	-0.137	0.001	-0.330	<0.001
Breast volume/dose*	0.645	<0.001	0.545	<0.001	0.514	<0.001
Tube voltage/dose*	0.783	<0.001	0.485	<0.001	0.608	<0.001
Tube current/dose*	0.938	<0.001	0.893	<0.001	0.912	<0.001
Exposure time/dose*	0.845	<0.001	0.798	<0.001	0.820	<0.001
Compression thickness/dose*	0.817	<0.001	0.508	<0.001	0.629	<0.001
Compression pressure/dose*	0.058	0.046	0.136	0.001	0.084	<0.001

*Spearman correlation test

Table 6. Comparison of radiation dose measurements and technical parameters in high dose and low dose groups

	Low dose < 75th percentile (Mean±SD)	High dose ≥ 75th percentile (Mean±SD)	p value
Image (n=1720)	1272 (74%)	448 (26%)	
Radiation Dose (mGy) (for each projection)	1.70±0.41	3.01±0.68	<0.001
Total Radiation Dose (mGy)	7.55±1.80	11.85±3.14	<0.001
Age (years)	56.5±11.1	49.0±7.0	<0.001
Voltage (kV)	26.6±1.2	28.4±1.6	<0.001
Tube Current (mAs)	82.8±19.3	128.7±27.1	<0.001
Exposure Time (ms)	623±153	907±216	<0.001
Breast Volume (ml)	630±340	1079±549	<0.001
Compression Thickness (mm)	33.1±10.5	46.4±10.3	<0.001
Compression Pressure (kg)	14.8±3.0	15.0±3.2	0.126

*Mann-Whitney U test, SD: Standart Deviation

Table 7. Logistic regression analysis results of factors affecting radiation dose with and without technical parameters

	RR (%95 CI)	p value	RR (%95 CI)	p value
Voltage (kV)	3.35 (1.16-9.66)	0.025	-	-
Tube Current (mAs)	1.71 (1.48-1.97)	<0.001	-	-
Exposure Time (ms)	0.95 (0.94-0.97)	<0.001	-	-
Compression Pressure (kg)	1.01 (0.89-1.15)	0.870	-	-
Breast Volume (ml)	1.001 (0.999-1.002)	0.336	1.002 (1.001-1.002)	<0.001
Age (years)	0.99 (0.92-1.05)	0.680	0.95 (0.92-0.99)	0.006
Compression Thickness (mm)	0.89 (0.76-1.04)	0.135	1.30 (1.25-1.36)	<0.001
Nondense/Dense Breast	0.59 (0.21-1.70)	0.332	0.09 (0.05-0.15)	<0.001

RR: Relative risk, CI: confidence interval

DISCUSSION

In this study, we performed mean dose calculations for our mammography examinations and investigated the factors affecting radiation dose. According to our study, in addition to the technical parameters of the mammography device, factors such as patient age, breast tissue density, breast volume, and compression thickness affect the radiation dose. The most significant finding of our study is that among the factors other than the technical parameters influencing the radiation dose in mammography, compression thickness has the highest impact, followed by breast volume, age, and finally breast density.

In the literature, the American College of Radiology Imaging Network (ACRIN) Digital Mammographic Imaging Screening Trial (DMIST) study reported a radiation dose range of 1.7-2.5 mGy for a single projection.[24] According to our results, the average radiation dose for a single mammographic projection was found to be 2.04 mGy, the average dose per breast for two projections was 4.08 mGy, and the average total radiation dose for a mammography examination was 8.17 mGy. Baek et al.[25], in their study conducted on the Korean population, found an average dose of 1.81 mGy for a single projection. In a study conducted in the USA, Hendrick et al.[26] reported an average glandular dose of 1.86 mGy for a single projection. In a study conducted in Turkey, Soylu et al.[27] reported a dose of 2.18 mGy. Taking into account the dose weighting factor (0.12) of the International Commission on Radiological Protection (ICRP), the average dose received by a breast in our study was calculated to be 0.49 mSv.[12] According to the recommendations of the ICRP and FDA, the mammographic dose should not exceed 3 mGy for a single projection. In Europe, a dose limit of 2.5 mGy has been specified. When compared to the information and published doses in the literature, it can be said that the mammographic radiation dose rate in our hospital is within the allowed average values.

In our study, we found that higher breast density in patients resulted in increased radiation dose. Similarly, in the literature, it has been noted that higher breast density leads to higher dose exposure.[28,29] When compared to Europe and America, Asian women have been found to have denser breast tissue and consequently higher dose exposure.[25] Additionally, Nguyen et al.[14] stated that while breast density contributes to dose exposure, its impact is not as significant when evaluated in conjunction with other factors. They mentioned that only 10% of the dose increase is attributable to breast density. Similarly, in our study, through regression analysis, we found that among factors other than technical parameters, breast density ranked fourth in terms of its impact, following compression thickness, breast volume, and age.

Considering our findings and the literature, it is important to emphasize that patients with denser breast tissue, who are generally younger and may have concerns about increased radiation exposure due to lifelong mammographic screening programs, should not postpone their mammographic screenings. Furthermore, it has been stated in the literature that breast cancer screening programs, particularly through screening mammography, have resulted in a decrease in breast cancer-related mortality in the United States, and the benefit obtained from early detection of breast cancer outweighs the risk of radiation exposure associated with it. Therefore, it is crucial for patients with dense breast tissue to prioritize regular mammographic screenings without undue concern about radiation exposure.[14-16]

According to our study, there was a negative correlation between patient age and radiation dose. Our findings of higher radiation exposure in younger patients are consistent with similar studies in the literatüre.[25,27] These results suggest that younger women, who generally have denser breasts, require higher doses for optimal imaging. In a study by Raed et al.[30] where they modeled the cancer risk associated with mammography screening, they noted that the most important parameters influencing the overall effective risk from screening were the age at which screening begins and the number of screenings, as tissue radiosensitivity decreases with age. There is an ongoing debate regarding initiating screenings at earlier ages, particularly for women at higher risk due to genetic factors or family history. Additionally, Hendrick et al.[26] reported that even at the same mammographic radiation doses, young women have a higher risk of developing breast cancer. Considering the relatively higher level of radiation exposure and these findings, it indicates the added importance of dose management for women undergoing mammography at a younger age. Individualized dosing may be beneficial, particularly for young patients with a high familial risk factor.

In our study, the average breast tissue volume was calculated to be 595 mL. In the literature, breast volume in Western women has been reported to range from 552 to 774 mL on average.[31,32] Our results fall within this range. Baek et al.[25] reported a smaller average breast volume (380-466 mL) in the Korean population. Breast density, on the other hand, has been found to be approximately 37-51% in Western women and 62-86% in Korean women. In our study, the proportion of dense breast tissue was measured as 36%, which is significantly lower compared to Korean women but closer to the lower limit of Western women.[31,33,34] Furthermore, a study conducted in Turkey also reported a dense breast ratio of 36%, which is in line with our findings.[27]

In a study conducted on approximately 25,000 women, it has been reported that women with larger breasts are exposed to 1.7 times higher radiation dose.[20] In our study, we also found that patients with larger breast volumes were exposed to higher radiation doses. There was a strong positive correlation between breast volume and radiation dose, and we identified breast volume as the second factor influencing radiation dose after compressed breast thickness. Additionally, it can be stated that breast volume also affects the factor identified as the most influential, which is compressed breast thickness. In patients with larger breast volumes, it is inevitable for the compressed breast thickness to be higher as well.

In our study, we found that compressed breast thickness was the factor that most significantly influenced radiation dose exposure, apart from technical parameters. This finding is consistent with the literature, where Nguyen et al.[14] reported that an increase in compressed breast thickness accounted for 80% of the increase in breast radiation dose. Applying compression to the breast not only improves image quality but also reduces radiation exposure. When compression is not applied properly, when the breast volume is large leading to increased compressed breast thickness, or when axillary and surrounding tissues enter the field in MLO images, the thickness of the compressed tissue increases. This necessitates the use of higher kVp or mAs with the automatic exposure feature of the device to overcome the increased tissue thickness.[14]

According to our results, tube voltage, tube current, and exposure time were the most significant technical parameters affecting radiation dose. These parameters are expected to directly influence dose increase since they are dependent on the radiation dose emitted by the device. However, comparing these data with other studies in the literature is useful for dose optimization and determining dose reduction strategies. In our study, we obtained an average of 27.1 kV and 94.8 mAs values in a single projection. These values are similar or close to those reported in many other studies in the literatüre.[17,18,25]

Our study has several limitations. Firstly, the relatively small sample size, single-center design, and local nature of the study limit its generalizability and ethnic diversity. Additionally, all images in our study were obtained from a single device. While this allows for a more homogeneous group, it hinders the comparison of different devices. Another limitation was the subjective decision-making involved in classifying breast density according to the BIRADS category. We did not have access to computer programs that automatically measure breast density and provide numerical results. Furthermore, some factors affecting radiation dose were closely related or even inseparable, making it difficult to separate their effects in statistical analyses, especially in regression analyses. Additionally, due to the retrospective design of the study, we could not analyze parameters such as body mass index that may influence breast density and volume. Finally, we did not seek additional dose measurement support to measure radiation dose. We conducted our study using the dose values provided by the device. While many studies in the literature use this parameter, obtaining more accurate results may be possible with the integration of dose measurement devices. Although our results show similarities with studies conducted in populations with different demographic characteristics, they cannot be globally generalized. In the future, prospective longitudinal studies evaluating the dose differences in repeated control mammography scans of the same patients may provide additional benefit to investigate the factors affecting the dose.

CONCLUSION

Based on the local data obtained in our study, the radiation doses of our mammographic screening procedure fall within internationally acceptable dose values. The most important factors influencing radiation dose are technical parameters such as tube voltage, current and exposure time. However, apart from technical parameters, compressive breast thickness is the most influential factor, followed by breast volume, age, and least of all, breast density, in affecting radiation dose. Multicenter and multinational prospective studies are needed to obtain generalizable results.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was carried out with the permission of Kastamonu University Clinical Researches Ethics Committee (Date: 05.07.2023, Decision No: 2023-KAEK-79).

Informed consent: Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process: Externally peer reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

Author Contributions: All the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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