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Comparison of Radiation Dose in Full Field Digital Mammography (FFDM) and Digital Breast Tomosynthesis (DBT)

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Introduction

Breast cancer is the most commonly diagnosed cancer and is the leading cause of death in women globally with an estimated 2.3 million new cases [1]. According to the cancer statistics, the incidence rate of breast cancer increased slightly by 0.3% per year over the recent five- year (2012-2016) [2]. In case of Nepal, GLOBOCAN 2020 suggested breast cancer is the third most common cancer with 9.6% new cases in both sex and is the second most common cancer in female of all ages with 1973 (17.1%) incidence of new cases of breast cancer [3]. Early detection of cancer is crucial for successful treatment and reducing risk [4].

Full Field Digital Mammography (FFDM) is the most effective and suitable breast imaging technique for screening and diagnosis of breast cancer [5]. Screening of breast using FFDM reduces the mortality rate due to breast cancer [6]. The American Commission of Radiology (ACR) guideline recommends the screening of breast starting for women above 40 years [7]. The screening mammography includes the craniocaudal projection (CC) and Mediolateral projection (MLO) of bilateral breast. Recent advances in FFDM have led to development of Digital Breast Tomosynthesis (DBT).

DBT is an advanced imaging technique which uses multiple low dose projection in either continuous or step and shoot mode along an arc over the breast providing thin slices of reconstructed image as well as 3D visualization of the breast which minimizes the superimposition of breast tissue [8]. DBT provides similar in-plane resolution to FFDM but higher out of plane resolution which improves detection of low contrast findings such as masses and architectural distortion [5]. It has similar sensitivity but higher specificity (DBT=91.3% and DM = 89.7%) with increased cancer detection rate of (DBT=0.685% and DM= 0.49%) compared to FFDM as well as reduced call back rate compared to FFDM [9]. Since the approval of DBT by FDA (Food and Drug Administration) in 2011 A.D., it is being widely used. But whether it should be used as a screening tool omitting DM is still a topic of on-going discussion.

The FFDM and DBT both uses ionizing radiation for imaging of breast. The use of ionizing radiation in DBT and FFDM imparts certain radiation doses to body. The unit of radiation dose measured in mammography is Average Glandular Dose (AGD) or Mean Glandular Dose (MGD). The average glandular dose to breast during mammography was reported in 1994 as 1.38 mGy per view in conference of ACR. The annual FFDM screen-

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ing and diagnostic procedure of women between 40-74 years induce 125 breast cancer in 100,000 subjects whereas it would diagnose 16,947 breast cancers early preventing the possible death [10]. Thus, resulting in more benefit than risk. The AGD measured for tomosynthesis is slightly higher than for mammography in same projection [11]. The radiation dose to patient should be as low as reasonably achievable (ALARA). Most of the researches have been conducted comparing the FFDM in conjuction with DBT with FFDM alone [12,13]. Very few published studies have discussed the dose imparted by FFDM and DBT-separately [8]. DBT is a recently introduced advanced modality of breast imaging in Nepal. This study aims to study the radiation doses imparted by FFDM and DBT and compare them. And to correlate the dose with compression thickness. This study is first of its kind in the country as there is lack of assessment of radiation dose in medical imaging facilities of Nepal.

Methods

In this cross-sectional study, 434 women were enrolled: 217 women from FFDM and 217 women from DBT, who came to department of radiology for breast imaging and were examined in same mammography imaging system. The patients with breast implants, a compressed breast thickness exceeding 8 cm and images with poor quality and artifacts were excluded from the study.

Imaging equipment

All the FFDM and DBT data were acquired in SIEMENS MAMMOMAT REVELATION using fully automatic exposure control (AEC) mode which determine technical exposure parameters such as X-ray tube voltage (kV)/tube current–time product (mAs) combinations and target/filter combinations automatically. No manual techniques were used for data acquisition. The dedicated mammography machine Siemen's Mammomat Revelation mammography unit with amorphous selenium detectors of 24* 31 cm, pixel pitch of 80 µmm, dual-track X-ray tube with Tungsten/ Rhodium (W/Rh) target/filter combination, DM and DBT was used for imaging. The system was subjected to regular quality control regarding technique, dosimetry and image quality by medical physicist.

The images were acquired in PRIME (Progressive Reconstruction Intelligently Minimizing Exposure) Craniocaudal (CC) and mediolateral oblique (MLO) projections. PRIME technology uses software-based anti -scatter reduction reconstruction method which can reduces the radiation dose upto 30% [14]. The target/filter combination for both FFDM and DBT was same (W/Rh).

For acquisition of DBT images, twenty-five projections over an X-ray tube rotation arc of +-25 from the vertical axis was performed[14]. Image reconstruction was performed immediately after image acquisition with a slice thickness of 1 mm and a reconstruction time of less than 60 seconds. The images were acquired in PRIME Craniocaudal (CC) and Mediolateral Oblique (MLO) with optimum compression.

The data such as age, projection (CC or MLO), compressed breast thickness, ESD and AGD were directly recorded from the mammography console.

The ESD and AGD values were directly recorded from the mammography DICOM files of unit console. The radiation dose between the FFDM and DBT were compared by per-view analysis. The reported radiation values were verified by the medical physicist during Quality Assurance (QA). The images were reported by the experienced radiologists.

Statistical analysis

The average glandular dose for each projection of FFDM and DBT was recorded separately and descriptive analysis was performed for each one. The AGD was correlated with compressed breast thickness using Pearsons's correlation. Finally, percent difference of average radiation dose of DBT and FFDM was calculated for each view. All the statistical analysis were performed using SPSS version 23.

Result

After the ethical approval form IRB NAMS, the study was conducted in 434 women patients coming to department of radiology mammography unit. Well informed consent for each individual was obtained before examination.

Table 1: Shows the descriptive analysis of average radiation dose in FFDM and DBT in different projection.

Projections	Average radiation dose in mGy (mean +- SD)
FFDM LCC	1.05+- 0.34
FFDM RCC	1.06 +-0.45
FFDM RMLO	1.24+-0.46
FFDM LMLO	1.20+-0.57
DBT LCC	1.87+-0.57
DBT RCC	1.87+-0.56
DBT RMLO	2.14+-0.73
DBT LMLO	2.10+-0.77

An independent sample t- test was conducted to compare the average glandular dose (AGD) in LCC, RCC, RMLO and LMLO for FFDM and DBT respectively. There were significant difference (t(432)=-17.1,p=0.0001), (t(432)=-18.1,p=0.0001), (t(432)=-15.3,p=0.0001) and (t(432)=-14.6,p=0.0001) in the dose with mean AGD for FFDM(m=1.05 m Gy, SD=0.35) ,((m=1.06 mGy, SD=0.34), (m=1.24 mGy, SD=0.45)and (m=1.20 mGy, SD=0.46) which was lesser than DBT(m=1.8 mGy, SD=0.57and(m=1.8 mGy, SD=0.56)), (m=2.1 m Gy, SD=0.73) , (m=2.1 mGy, SD=0.77) in LCC, RCC,RMLO and LMLO respectively. The magnitude of difference in mean (mean difference =0.045, 95% CI) , (mean difference =-0.81, 95% CI), (mean difference =-0.90, 95% CI)and (mean difference =-0.89, 95% CI) respectively was significant as shown in table 2.

Table 2: Independent t-test to compare AGD in FFDM and DBT in different projections.

Projections	t-value	df(degree of freedom)	p-value	Mean		Mean difference	
				FFDM	DBT		C.I.
LCC	-17.1	432	0.0001	1.05+-0.35	1.8+-0.57	-0.045	95%
RCC	-18.1	432	0.0001	1.06+-0.34	1.8+-0.56	-0.81	95%
RMLO	-15.3	432	0.0001	1.21+-0.45	1.24+-0.73	-0.90	95%
LMLO	-14.6	432	0.0001	1.24+-0.46	1.20+-0.77	-0.89	95%

Pearson correlation of compressed breast thickness and average glandular dose was found to be moderately positive and statistically significant for all projections: LCC, RCC, RMLO and LMLO in both FFDM and DBT with r and p value as shown in the Table 3. This shows that an increase in compressed breast thickness would lead to increase in average glandular dose. Figure 1 a, b c and d also depict the same association.

Table 3: Correlation between compressed breast thickness and different projection in two modalities.

Projection	R value	P value
FFDM LCC	0.57	0.0001
FFDM RCC	0.57	0.0001
FFDM RMLO	0.54	0.0001
FFDM LMLO	0.63	0.0001
DBT LCC	0.42	0.0001
DBT RCC	0.44	0.0001
DBT RMLO	0.45	0.0001
DBT LMLO	0.49	0.0001

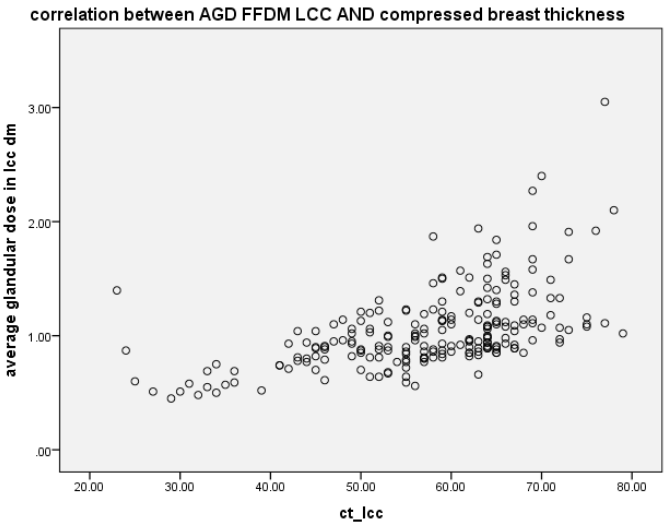

Figure 1A: Correlation between AGD and compressed breast thickness in FFDM in LCC.

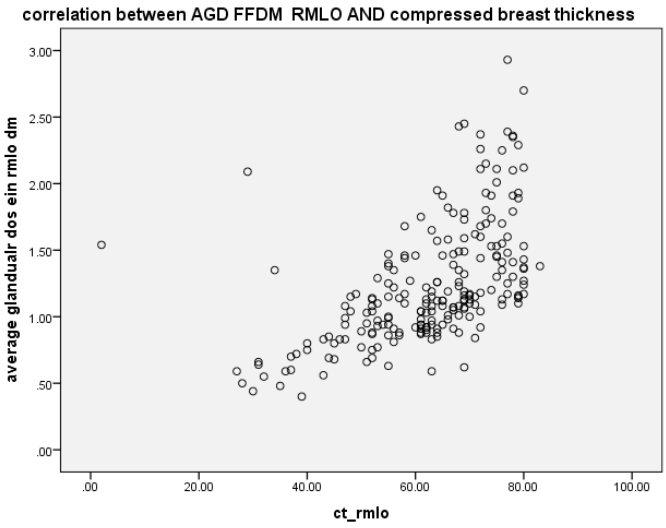

Figure 1B: Correlation between AGD and compressed breast thickness in FFDM in RMLO.

Discussion

The chosen metric for quantifying the radiation dose received in mammography is Average Glandular Dose. AGD depends on various factors such as kVp, mAs, target/filter combination, compressed breast thickness and breast composition. Glandular tissue is the most radiosensitive part of the breast. The ICRP tissue weighting factor for breast is 0.12 and the radiation weighting factor for x-rays used in mammography is1 [15].

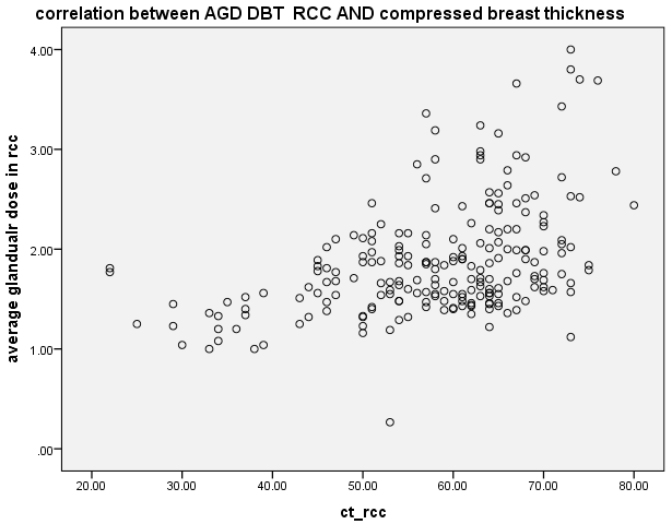

Figure 1C: Correlation between AGD and compressed breast thickness in DBT in RCC.

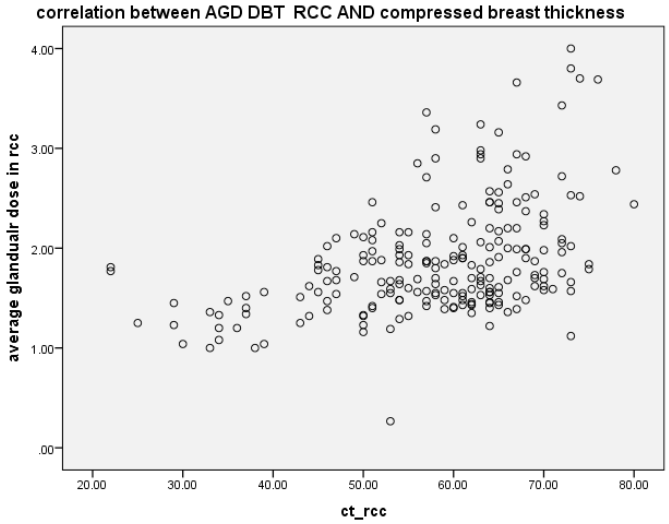

Figure 1D: Correlation between AGD and compressed breast thickness in DBT in LMLO.

The ACR recommends maximum permissible dose for mammography is 3mGy per view [16]. In our study, the AGD lies well below this limit.

Comparison of radiation dose in FFDM and DBT

The findings from this study suggest that the average radiation dose in full field digital mammogram is lower compared to digital breast tomosynthesis for each individual projection and in overall. The mean AGD in FFDM is 1.05 mGy,1.06mGy and 1.24 mGy and 1.20 mGy in CC and MLO view of the left and right breast respectively. This is lower compared to the study performed by Khadka *et al* [17] in which they found a mean AGD as 1.21 mGy and 1.34mGy in CC and MLO view respectively. In another study conducted by Gennaro *et al* [8], the mean AGD was 1.36mGy and 1.37 mGy in CC and MLO. The higher radiation dose in MLO view than in CC view is because of inclusion of pectoral muscle with higher attenuation resulting in higher radiation dose. The lower radiation dose in digital mammography in our study is primarily attributed to the PRIME (Progressive Reconstruction Intelligently Minimizing Exposure) technology used in acquisition of the images which uses software-based anti -scatter reduction reconstruction method resulting in reduction of the radiation dose.

The AGD in DBT was 1.8 mGy, 1.8 mGy, 2.1 mGy and 2.1 mGy in CC and MLO view of the left and right breast respectively. This finding is similar to study performed by Gennaro *et al* [8] in which the AGD was 1.8 in CC and 1.8 in MLO. The AGD in MLO in our study is slightly higher than in this study. This might be related to difference in compressed breast thickness (mean compressed breast thickness is 48 mm whereas in our study mean compressed breast thickness in MLO view is 61mm). In OSLO trial, the mean AGD in DBT was found 1.95mGy which is similar to our study [12].

The results of this study point higher radiation dose delivered to patient undergoing DBT than those undergoing FFDM in all projections and in overall. It was found that DBT AGD in CC is 80% higher in average compared to FFDM AGD whereas DBT AGD in MLO is 76% higher in average compared to FFDM AGD. In tomosynthesis, thin reconstructed images remove the superimposition of tissues resulting in poor contrast and hence more penetrating x-rays are used which can be obtained by increasing the beam filtration, kvp in order to obtain adequate image quality of the thinly reconstructed images. A population-based study performed by Gennaro *et al* found increase of 38% [8]. In Oslo Trial study they found increase of 23% dose in DBT than in FFDM [12]. The Malmo trial found a difference of 33% [10]. The possible result in higher dose difference in our study may be due to higher number of projection being taken during the tomosynthesis. In Gennaro *et al* [8] and OSLO trial [12], they used only 15 projections whereas in our study the machine uses 25 projections for acquisition of tomosynthesis. Another possible reason of the difference may be because of lower FFDM AGD and higher DBT AGD contributing to higher percent difference.

Association with compressed breast thickness

The results from this study suggests that the average glandular radiation dose is higher in patient with higher compressed breast thickness in both the modalities and in all projections. This is similar to the studies performed by Khadka *et al* [17] and Gennaro *et al* [8]. With the increase in breast thickness, uniform contrast is obtained by increasing the penetration of x-rays by increasing the kvp resulting in higher radiation dose.

The main limitation of this study is that we used the radiation dose report directly from the mammography unit as provided by the SYNGOVIA software. However, quality assurance program includes comparing the measured AGD with the AGD generated in the console regularly by well experienced medical physicist. The reported doses were within the measurement error margin. Another limitation is that the comparison of DBT and FFDM was based on limited number of populations in a hospital with single mammography imaging system. This limits the generalizability of the dose difference. Hence further studies are required using different imaging system with large sample population.

Conclusion

The radiation dose delivered in DBT is significantly higher compared to FFDM. Despite the potential benefit from the DBT in diagnosis and recall rate, the increase in radiation dose demand considerations before using DBT as a screening modality of breast cancer and should be used with proper understanding of the radiation dose.

Author declarations

Ethical consideration

The ethical approval was obtained from IRB NAMS prior to the conduction of this research study. Well informed consent (both verbal and written) was taken from the patients before performing the examination.

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Conflict of interest

The author declares no conflict of interest.

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