**Radiation risk from digital breast tomosynthesis screening – a comparison with full field digital mammography**

**Abstract**

**Objectives:** To compare the radiation risk from digital breast tomosynthesis (DBT) screening with that from full field digital mammography (FFDM) screening.

**Method:** To simulate compressed breasts, two Perspex-polyethylene breast phantoms were used, one phantom for compressed breast in craniocaudal and the other for compressed breast in mediolateral oblique. An adult ATOM dosimetry phantom was loaded with high sensitivity thermoluminescence dosimeters; the phantom was then positioned on Hologic Selenia Dimensions mammographic machine to imitate DBT and 4-view FFDM screening. Organ radiation doses were measured from 4-view DBT and 4-view FFDM (craniocaudal and mediolateral oblique views for each breast). Organ radiation doses were used to calculate effective dose from one screening session.

**Results:** Mean glandular dose (MGD) for DBT was 3.6 mGy; MGD for FFDM was 2.8 mGy. For DBT, other organs (e.g. thymus, lungs, salivary glands, thyroid, contralateral breast and bone marrow) radiation dose was also higher than for FFDM. The use of DBT for breast cancer screening increases the effective dose (E) of one screening session by 22%. E for DBT was 0.44 mSv; E for FFDM was 0.34 mSv.

**Conclusion:** The use of DBT for breast cancer screening increases the radiation dose to screening clients.

**Keywords**

Tomography, dosimetry, organ dose, breast cancer

**Introduction**

Digital breast tomosynthesis (DBT) involves relative motion between the X-ray source, image receptor and patient [1]. DBT images were firstly produced on 1997 by Niklason, Christian [2], who used a movable X-ray tube and fixed image receptor to image the American College of Radiology (ACR) breast phantom and several mastectomy samples. DBT involves multiple exposures of the breast from different angles [1] and its image acquisition geometry is comparable to that of full field digital mammography (FFDM). The only difference between DBT and FFDM is, in DBT the X-ray tube moves at specific angular intervals around the compressed breast which rests on the static image receptor [3]. The range of X-ray tube movement is different for each DBT manufacturer. For instance, the range of X-ray tube movement in Hologic Selenia Dimensions is 15 degrees, -7.5 to +7.5 degrees, and produces 15 images per view [4]. Overall DBT is used to produce several high spatial resolution, cross-sectional and low dose images of breast tissue for each mammographic projection. Consequently, DBT helps to minimise breast tissue superimposition resulting in more clearly defined tumours [5].

The clinical performance of DBT, for both screening and diagnostic purposes, was evaluated in many studies [6]. For screening, the majority of these studies reported that integrated DBT with 2D FFDM may increase breast cancer detectability [7, 8] and reduce the recall rate [8, 9]. This came at a cost – it increased examination and interpretation time [10]. However, Lang, Andersson [11] reported that one-view DBT screening significantly increases breast cancer detectability and recall rate. For diagnostic purposes, DBT has been reported to have a comparable diagnostic accuracy to spot-view mammography [12] and significantly better accuracy than supplemental diagnostic mammograms [13].

Similar to other breast imaging modalities, mean glandular dose (MGD) is used as a radiation risk indicator in DBT. For single view DBT, the MGD is the total MGDs of all projections in the tomographic scan [14]. In the early stage of DBT development, Niklason, Christian [2] reported that DBT MGD is comparable to that from single view screen-film mammography. MGD from DBT is currently reported to be one to two times more than that from single view FFDM [15]. Feng and Sechopoulos [4] estimated the MGD resulted from single craniocaudal view acquired by FFDM and DBT. They concluded that DBT resulted in higher MGD than FFDM and this difference increases as the breast thickness increase.

Other organs radiation dose, excluding exposed breast tissue, from DBT was assessed by Baptista, Di Maria [15]. They used Monte Carlo simulation software to estimate the radiation dose received by several radiosensitive organs within the female reference voxel Laura phantom from DBT exposure. In order to simulate different breast thickness, the organ radiation doses were estimated using different tube potentials, 24-34 kVp, and 100 mAs. They found that the highest radiation dose was received by ipsilateral lung, thyroid and contralateral lung. Presently there is limited published literature that considers the radiation dose to other organs from DBT. Accordingly, the aim of this work was to measure, experimentally, the other organs radiation dose from DBT and compare these data with organs radiation dose from FFDM.

**Materials and Method**

For organs dose measurement, a dual function (FFDM and DBT) Hologic Selenia Dimension machine was used. This machine was operating within the acceptable quality control criteria recommended by National Health Services Breast Screening Programme (NHSBSP). For both FFDM and DBT, automatic exposure control (AEC) was used to expose a breast phantom. Thermoluminescent dosimeters (TLDs) loaded within an adult human ATOM dosimetry phantom were used to measure the radiation dose received by radiosensitive organs determined by the International Commission on Radiological Protection (ICRP) [16].

***Breast Phantom and MGD Calculation***

A polymethyl methacrylate-polyethylene (PMMA-PE) breast phantom, as suggested by Bouwman, Diaz [17], was used to simulate the compressed breast. This was 53 mm thick and comprised 32.5 mm PMMA and 20.5 mm PE slabs. Two breast phantoms were used: semicircular with 95mm radius to simulate the compressed breast in CC view; 100mm x 150mm rectangular to mimic the breast in MLO view.

For FFDM, the MGD was calculated using the equation described by Dance, Skinner [18]:

*MGD=K.g53.c53.s*

Where *K* is the incident air kerma for the phantom measured at midpoint in the lower surface of the compression paddle about 4cm from the chest wall using solid-state dosimeter (Unfors Multi-O-Meter dosimeter, Billdal, Sweden); *g53* is a factor to convert the incident air kerma to MGD for a 53mm thick standard breast; *c53* is a conversion factor which allows for the glandularity of 53mm thick standard breast; *s* is the spectral correction factor.

For DBT, the incident air kerma was measured using three TLDs, to obtain an average reading minimizing random error. TLDs were utilised instead of the Unfors solid state dosimeter because the solid state dosimeter cannot measure the total air kerma for a pulsing X-ray beam. These three TLDs were fixed at the midpoint 4 cm from the chest wall side on the lower surface of the compression paddle through which the X-rays enter to the breast. Then the MGD was calculated using the equation described by Dance, Young [19]:

*MGD=KT.g53.c53.s T*

Where *KT*and *T* are the total incident air kerma and total ‘tomo’ factor for complete scan, respectively. The values for *T* factor are tabulated by Dance, Young [19] for Hologic Selenia Dimension system for each breast thickness.

***Organs Dose Measurement***

Using the method described by M. Ali, England [20], organ doses were measured by TLDs loaded within ATOM dosimetry phantom. 280 TLDs were used to measure the radiation dose received by 20 radiosensitive organs and tissues. These organs included adrenals, brain, bone marrow, contralateral breast, gall bladder, heart, intestine, kidneys, liver, lungs, oesophagus, ovaries, pancreas, salivary glands, spleen, stomach, thymus, thyroid, urinary bladder and uterus. In order to minimise random error, the breast phantom was exposed three times for each mammographic view then the dose data was divided by three to obtain the organ doses from a complete screening session (CC and MLO for each breast). This procedure was conducted for both FFDM and DBT (Figure 1).

(a) (b)

(Figure 1) Shows the adult human ATOM dosimetry and breast phantom positioned on Hologic Selenia Dimensions mammography machine (a) in cranio-caudal position (b) in medio-lateral oblique position.

***Radiation Risk Estimation***

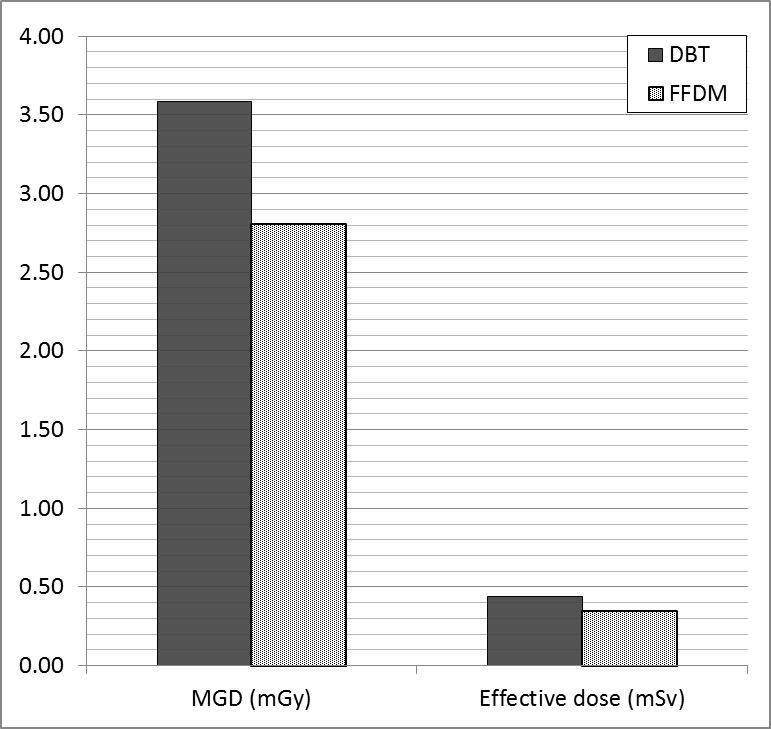
In this study effective dose was used to compare the radiation risk from DBT screening with that from FFDM screening. The effective dose was calculated using the tissue weighting factors published by the ICRP [16] as follow:

*E= ΣwT HT*

Where *E* is the effective dose, *wT* is the tissue weighting factor and *HT* is the radiation received dose by tissue *T*.

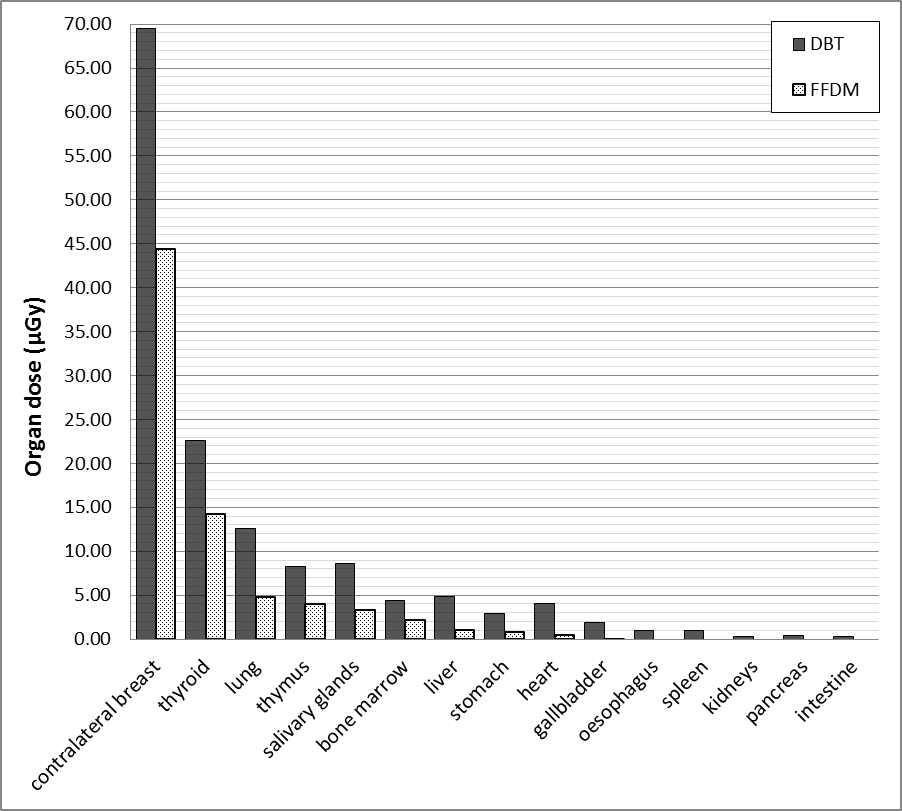
**Results**

For 4-view DBT screening, MGD was increased from 2.81 mGy, for FFDM, to 3.58 mGy. Similarly, effective dose was increased from 0.34 mSv to 0.44 mSv, when changing from FFDM to DBT screening (Figure 2).



(Figure 2) Shows the MGD and effective dose of one screening session when using DBT as compared to FFDM.

The radiation dose received by other tissues, other than the exposed breast, was also increased when using DBT for screening as compared to FFDM. For both FFDM and DBT the highest radiation dose was received by contralateral breast tissue. Oesophagus, spleen, kidneys, pancreas and intestine do not receive radiation dose with the use of FFDM. However, they received a measurable radiation dose (≤ 1µGy) when using DBT (Figure 3).



(Figure 3) Demonstrates the radiation dose received by body tissues from one screening session by DBT compared with that by FFDM.

**Discussion**

Several studies considered the MGD arising from DBT, however, a limited number of studies have considered the radiation dose to other body tissues, other than exposed breast. Undoubtedly, the use of DBT for 4-view breast cancer screening results in higher MGD than that when FFDM is used but DBT has better breast cancer detectability than FFDM. In our current study the MGD from DBT was 3.58 mGy and this was more than that from FFDM (Figure 2). This DBT MGD is slightly more than the acceptable mammographic MGD range recommended by the European Commotion [21].

Regarding the radiation dose to other organs, no research has been identified which measuredorgan dose *in vivo* using DBT and this is a novel point within our work. The mathematical simulation by Monte Carlo software has previously used to estimate organ dose from DBT. Baptista, Di Maria [15] estimated the radiation dose received by seven radiosensitive organs from a craniocaudal view DBT, using the Siemens MAMMOMAT Inspiration. Baptista, Di Maria [15] and his colleague published the radiation dose from each X-ray tube rotation angle from 0 to +24 degree in 2 degree steps and then they duplicated their data to obtain the radiation dose for a complete DBT scan. However, this is not the exact case in DBT wherein the X-ray tube moves in both directions resulting in different radiation exposures in each direction. Their results are similar to ours in that the DBT generated more organ radiation dose than FFDM. However, they found that the highest radiation dose, after the exposed breast, was received by left lung and thyroid but we found that the highest dose received by contralateral breast and thyroid making the lung dose ranks third as seen in (Figure 3).

The use of DBT increases the effective dose of one screening session by 22% compared to FFDM; the figures were 0.44 mSv and 0.34 mSv, respectively (Figure 2).

Since DBT from different manufacturers has different design, further work is required to include more mammographic machines from different manufacturers to investigate the effect of machine design on radiation risk.

**Conclusion**

The use of DBT for breast cancer screening increases the radiation dose received by body tissues and organs. Consequently, it increases the effective dose of 4-view screening session but this increment tended to be within the acceptable range. From a dosimetric view, the 4-view DBT can be used for breast cancer screening especially for high breast density women in spite of its higher radiation risk when compared to FFDM.

**Footnotes**

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