Original Investigation

Automated Breast Density Computation in Digital Mammography and Digital Breast Tomosynthesis: Influence on Mean Glandular Dose and BIRADS Density Categorization

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Rationale and Objectives: The study aimed to compare the breast density estimates from two algorithms on full-field digital mammography (FFDM) and digital breast tomosynthesis (DBT) and to analyze the clinical implications.

Materials and Methods: We selected 561 FFDM and DBT examinations from patients without breast pathologies. Two versions of a commercial software (Quantra 2D and Quantra 3D) calculated the volumetric breast density automatically in FFDM and DBT, respectively. Other parameters such as area breast density and total breast volume were evaluated. We compared the results from both algorithms using the Mann-Whitney *U* non-parametric test and the Spearman's rank coefficient for data correlation analysis. Mean glandular dose (MGD) was calculated following the methodology proposed by Dance et al.

Results: Measurements with both algorithms are well correlated ($r \geq 0.77$). However, there are statistically significant differences between the medians ($P < 0.05$) of most parameters. The volumetric and area breast density median values from FFDM are, respectively, 8% and 77% higher than DBT estimations. Both algorithms classify 35% and 55% of breasts into BIRADS (Breast Imaging-Reporting and Data System) *b* and *c* categories, respectively. There are no significant differences between the MGD calculated using the breast density from each algorithm. DBT delivers higher MGD than FFDM, with a lower difference (5%) for breasts in the BIRADS *d* category. MGD is, on average, 6% higher than values obtained with the breast glandularity proposed by Dance et al.

Conclusions: Breast density measurements from both algorithms lead to equivalent BIRADS classification and MGD values, hence showing no difference in clinical outcomes. The median MGD values of FFDM and DBT examinations are similar for dense breasts (BIRADS *d* category).

Key Words: Breast density; digital mammography; digital breast tomosynthesis; BIRADS categorization; mean glandular doses.

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INTRODUCTION

Millions of women undergo breast cancer screening with full-field digital mammography (FFDM) every year. The assessment of breast density has been an important component of mammography screening reports that provides information on mammographic sensitivity and relative risk of breast cancer. Recently, legislation in several US states requires that patients be informed about breast density and the potential for decreased mammographic sensitivity and increased cancer risk (1). Lately, digital breast tomosynthesis (DBT) has been proposed as an imaging modality to overcome the limitations of the conventional mammography regarding thicker or dense breasts. The inclusion of DBT as a screening tool is currently under debate (2), and the higher dose delivered in DBT with respect to digital mammography is a matter of great concern (3–5).

The breast is one of the most radiosensitive organs, and the estimation of radiation dose delivered to breast tissue is

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critical in screening programs. It is generally assumed that glandular tissue is the most radiosensitive component in the breast, with adipose tissue presenting a minimal risk of cancer development (6). Therefore, the mean dose delivered to the glandular tissue within the breast has been established as the standard risk metric in mammographic examinations (7). Because of the intricacy of having reliable information about breast glandular distribution, the mean glandular dose (MGD) was estimated for a long time by assuming in all patients a breast tissue composition of 50% fibroglandular (or dense) and 50% adipose.

The first studies comparing the automatic exposure control response for different materials (simulating breast compositions) and patients (8–11) showed dependence of breast composition on patient-related factors such as age and breast thickness. These results prompted the development of novel breast models to replace the simplistic 50%/50% assumption. Dance et al. (12) suggested a lower density of 33% for a standard breast (5-cm thickness, women aged 50–64 years). This is currently the most widely accepted breast composition model for MGD assessment. Moreover, different density values from 3% to 100% were also assigned to thicknesses from 2 to 11 cm in order to provide a more realistic estimation of MGD values (12).

Methods to achieve more reliable breast density values were developed as part of studies aiming to demonstrate the association between breast density and breast cancer (13,14). The employed methodologies involve qualitative and quantitative measurements (15–18). The development of volumetric techniques has provided more accurate breast density assessments (19–21), also favored by the advent of digital mammography and three-dimensional (3D) breast imaging techniques (22,23). Yaffe et al. (24) reported breast density values lower than 45% for 95% of the women in their study, using computed tomography breast images and an algorithm to extract information from mammograms. In general, there is a high agreement on breast density values lower than 35% for most women participating in the referred studies.

Later developments have led to commercially available algorithms for automatic computation of breast density. The most common Quantra (Hologic Inc., Bedford, MA) (25) and Volpara (Volpara Health Technologies Limited, Wellington, NZ) (26) work directly on raw digital mammograms (FFDM) and compute the volumetric density from the image pixel values and data about breast thickness and exposure conditions. Recently, an extension of Quantra is also available operating on raw DBT projections (27).

This paper focuses on the comparison of breast density values measured using two versions of Quantra operating on FFDM and DBT images, respectively, and their respective BIRADS (Breast Imaging-Reporting and Data System) categorization. We also analyze the impact of individualized breast density values on MGD for both FFDM and DBT modalities. Finally, we compare the results with the MGD values calculated using the breast glandularity estimated with the methodology of Dance et al. (12,28,29).

MATERIALS AND METHODS

Image Acquisition

FFDM and DBT images were acquired with a Hologic Selenia Dimensions system version V1.8.3.63 with C-View 2.0.1.1. (Hologic Inc.), operating in fully automatic exposure control (Autofilter). Anode/filter combinations for FFDM acquisition were W/Rh and W/Ag depending on the compressed breast thickness. DBT images were acquired using W/Al and the grid was retracted. In both modalities, the automatic selection of tube kilovoltage is a function of the compressed breast thickness, and the tube loading depends on the breast attenuation previously determined from a single low-dose exposure. In the DBT modality, the device acquires 15 low-dose projections over 15° (−7.5 ± 7.5). The system is equipped with a selenium detector, with a spatial resolution of 70 μm/pixel for FFDM acquisitions and 140 μm/pixel for DBT acquisitions (binning mode).

Study Population

Patient examinations were collected for 3 months from November 2015 to January 2016 in our collaborator institution. Patients were consecutively enrolled to exclude a selection bias. The only criterion for patient selection was to exclude patients with verified pathologies. A total of 561 patients (mean age, 54 years; range, 32–86 years) attending the breast department for diagnostic or opportunistic screening were enrolled in the study. There were 227 women under 50 years old (median: 44 years) and 334 women older or equal to 50 years old (median: 59 years). The routine examination protocol consists of two views per breast (craniocaudal [CC] and mediolateral oblique [MLO]) in combo HD mode (FFDM and DBT under a single compression). A total of 2244 images were collected for the study. Anonymized patient data (age and breast thickness) and exposure parameters (anode/filter combination, kilovoltage, tube loading, laterality, and view) were retrieved from the DICOM (Digital Imaging and Communications in Medicine) headers.

Breast Density Estimations

FFDM and DBT images were subsequently processed with the algorithms 2D Quantra 2.1.1 (Q2D) (30) and 3D Quantra 2.1.1 (Q3D) (27) (Hologic Inc.), respectively. Both algorithms operate in the same fashion, and they first estimate the volumetric breast density (Vbd) for each view (per-image Vbd).

The Vbd (%) is calculated by dividing the total volume of fibroglandular breast tissue (Vfg) over the total volume of the breast (Vb). The estimation of Vfg above each pixel in the image is done by taking into account breast properties (attenuation and thickness) and exposure factors. These values are later added to obtain the total volume (cm^3) of Vfg. The Vb is derived from the breast thickness under compression and the whole outline of the imaged breast, compensating for