Pressure-based Breast Compression Guidance in Digital Breast Tomosynthesis

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This article summarizes the results of a recently published paper evaluating the introduction of a pressure sensing flexible paddle in digital breast tomosynthesis (DBT) [1]. We used a flexible paddle capable of performing pressure-assisted compression. In this system, eight lights on the paddle are successively illuminated to indicate the extent of breast compression (one LED lamp lit every 1.9 kPa). The compression process can be carried out by the technologist, or by the woman participant herself using a remote control device. We found that using this new type of paddle, with or without the involvement of the woman, both the women and technologists reported an improved experience of the whole compression process, showing the potential of the system to decrease the negative perception commonly associated with breast compression in mammography and DBT. Such improvement in the perception of the compression experience may lead to higher continued participation levels in breast cancer screening programs. In addition, variability in the applied compression pressure, the mean breast thickness and the glandular dose were all reduced significantly, thus improving standardization across visits and examination sites.

INTRODUCTION

In order to acquire high quality images in mammography or digital breast tomosynthesis (DBT) examinations, a certain degree of breast flattening is essential. However, there are no internationally accepted rules or guidelines as to the optimal level of breast flattening. In general, local guidelines that are frequently used aim for a target force or a range of forces, in a process where the eventual compression force applied is generally determined by the technologist's experience and feedback from the patient. The absence of a standardized compression practice results in large variations in the compression actually applied [2, 3]. Another important issue related to breast compression is the pain experienced by the patient, a common reason for the woman to drop out of or avoid breast screening programs. As a result of the combination of these issues, together with the advances made in mammography over the last few years, it has become apparent that there is a need for breast compression standardization. This would ensure that compression levels stay within reasonable and physiologic boundaries to avoid the negative consequences of using too high — or too low — compression forces and pressure [4].

Over the past few years, approaches such as flexible compression paddles [5], pressure-based compression [6], patient-controlled compression [7] and others, have been introduced as separate methods, with studies showing that each individual method had a positive effect both on patient satisfaction and/or breast compression.

However, the impact of the combined use of these three methods on patient discomfort and compression variability is unknown.

The primary aim of this study was to measure the effect of a pressure-based flexible paddle on compression parameters and its influence on the technologist's and patient's overall experience of DBT. Additionally, our study aimed to assess the difference between a remote-controlled, pressure-based, patient-assisted compression process on the one hand and a

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pressure-based, standard technologist-assisted compression process on the other.

FLEXIBLE COMPRESSION PADDLES, PRESSURE-BASED COMPRESSION AND PATIENT-CONTROLLED COMPRESSION

Mammography and DBT systems are frequently (but not always) equipped with flexible paddles, which have the ability to adjust to the shape of the breast during compression through the application of a limited amount of tilt, so improving patient comfort.

In pressure-based compression, the parameter of pressure, expressed in kilopascals (kPa), is used instead of force, to assess the degree of breast compression. To enable pressure-guidance, the compression paddle of the mammography system is equipped with a conductive foil that is transparent to light and X-rays [6]. Changes in capacitance between the breast and the foil, as the breast is compressed, can be used to measure the contact area (A, in cm^2) of the breast with the paddle. The ratio between the applied compression force and the breast contact area yields the mean contact pressure in that area ($P = F/A$)[6]. This approach has been studied in conventional 2D mammography, using a rigid paddle but not yet for flexible paddles in DBT.

In patient-controlled compression, patients are able to control the movement of the paddle by use of a remote control device they hold in their hand. After positioning of the breast and initial compression by the technologist, the remote control device becomes active, enabling the patient to control and finalize the compression herself.

STUDY PROCEDURE

In our study, pressure-based flexible paddles were used on a Senographe Pristina DBT system (GE Healthcare, Chicago, IL). Mean compression pressure is calculated in real time by the smart paddle and is displayed to both the technologist and the patient through a progressive eight-light LED indicator display located at the rear of the paddle. As shown in Figure 1, the lights provide a visual indication of the pressure applied. As the compression pressure is increased, the eight LEDs light up progressively, with a light being illuminated after each pressure increase of 1.9 kPa. When the target pressure range (8–13.9 kPa) is achieved, LED lights #5–#7 glow pink.

In one group of patients in our study, the compression was applied and controlled completely by the technologist, while in another group the women being examined actively participated in the compression process by using the remote control device. In both groups, the original positioning of the breast on the paddle was carried out by the technologist. In the technologist compression group, the technologist was instructed to compress the breast within the target pressure range (LED lights #5–7). In the patient-assisted compression group, after the positioning of the breast, the technologist applied an initial compression force of at least 3 daN. The woman being examined was then invited to increase the compression to the target pressure range using the hand-held Pristina Dueta remote control device (GE Healthcare, Chicago, IL).

A total of 152 women gave their informed consent to take part in the study. Of these, 103 participants (patient-assisted compression, n = 50; technologist compression, n = 53) had prior examinations available for data comparison and also successfully completed a questionnaire to evaluate their experience in terms of comfort and overall satisfaction.

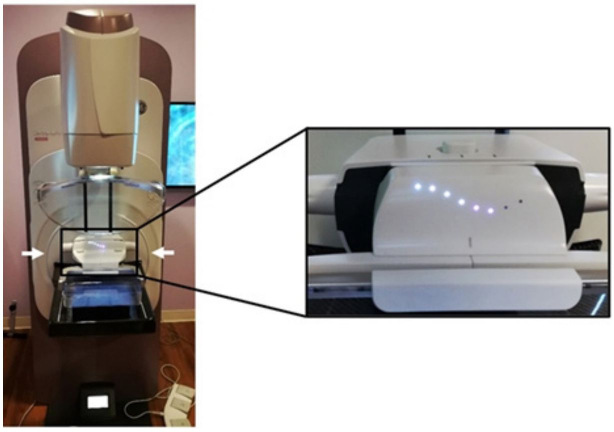


Figure 1. Research version of a flexible pressure-based compression paddle which is easily fitted to a Senographe Pristina DBT system (GE Healthcare, Chicago, IL). Eight light emitting diode (LED) lights indicate the pressure level to the technologist and participant. LED lights #5–7 (pink) indicate the target pressure range (8–13.9 kPa)

PATIENT AND TECHNOLOGIST EXPERIENCE

From the answers in the questionnaire, it was found that 81% of the participating women judged the compression as being similar or more comfortable compared with previous examinations. Out of all the women, 87% stated that they would recommend pressure-based compression to friends. Of the women in the patient-assisted compression group, a total of 98% indicated that they would be happy to recommend this method to friends.

The technologists also completed a separate questionnaire whose results showed that the technologists found that in all cases pressure-based compression was easier to explain to the women. In all except one case, pressure-based compression helped to involve the patient in the compression and in 98% of the cases, technologists found that the compression time decreased.

COMPRESSION PARAMETERS

Of the 103 participants, 94 had complete sets of four DBT images — one craniocaudal (CC) view and one mediolateral oblique (MLO) view for each breast — from prior examination and the current study. Since the compression parameters of contact area (cm^2) and breast volume (dm^3) were not available in the DICOM header of both prior and study mammographic views, they were calculated by a digital image processing software tool (Volpara Enterprise v.3.3.2, Volpara Solutions LTD, Wellington, New Zealand). The compression parameters that were available in the DICOM header—breast thickness (mm, distance between the detector and paddle), applied force (N), average glandular dose (mGy), and breast density (%)—were also obtained from the user interface of the Volpara digital image processing software tool.

As shown in Figure 2, regression lines show a linear relation between force applied and contact area during pressure-guided compression for both CC and MLO views, something that was absent during conventional compression. The standard deviation force increased by 66% for CC views ($P < 0.0001$) and 44% for MLO views ($P < 0.0001$).

As for pressure and the contact area, regression lines indicate a negative linear relationship during conventional compression

[Figure 3]. During pressure-based compression, pressure was no longer dependent on contact area. There was a reduction in pressure variability of 50% for CC views (P < 0.001) and of 34% for MLO views (P < 0.0001).

For the other compression parameters; breast thickness decreased on average by 4.5 mm for the CC view (P < 0.0001) and decreased by 5.8 mm for the MLO view (P < 0.0001). The mean breast contact area for the CC view increased from 90.83 ± 41.07 cm² to 94.47 ± 41.43 cm² (P < 0.0001) and for the MLO view increased from 122.82 ± 39.00 cm² to 132.17 ± 42.37 cm² (P < 0.0001). The breast volume decreased for both the CC view (0.77 ± 0.40 dm³ to 0.70 ± 0.34 dm³, P < 0.0001) and the MLO view (0.93 ± 0.47 dm3 to 0.88 ± 0.43 dm³, P < 0.001). Breast density decreased in the CC view from 8.00 ± 6.76% to 7.47 ± 6.11% (P = 0.01) and remained similar in the MLO view (7.81 ± 6.39% to 7.65 ± 6.67%, P = 0.4).

In a sub analysis of 100 paired views, where both prior and current study examinations were acquired using the same Senographe Pristina and X-ray detector, the average glandular dose was similar for CC views (conventional compression: 1.57 ± 0.30 mGy, pressure based compression: 1.60 ± 0.39 mGy [P = 0.38]).

When comparing pressure-based compression between technologist compression (n = 50 participants) and patient-assisted compression (n = 44 participants), the mean compression parameters were similar in both groups except for the average glandular dose in the CC view where the mean dose was higher in the patient-assisted compression group (1.57 ± 0.36 mGy) compared with the technologist compression group (1.48 ± 0.21 mGy, P = 0.04).

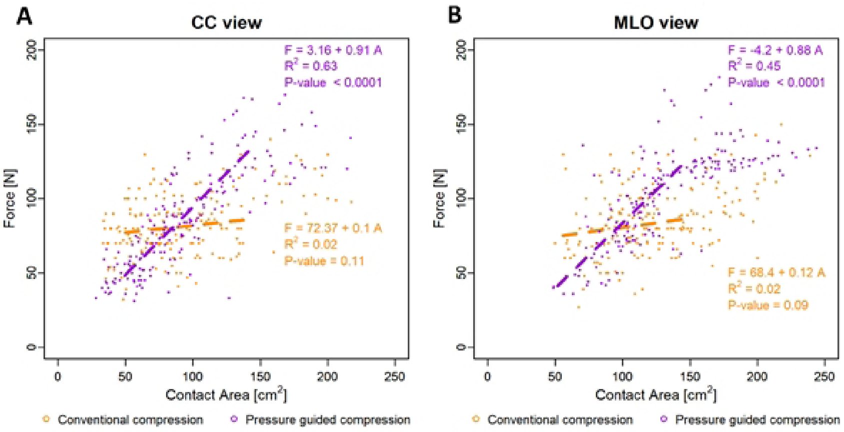
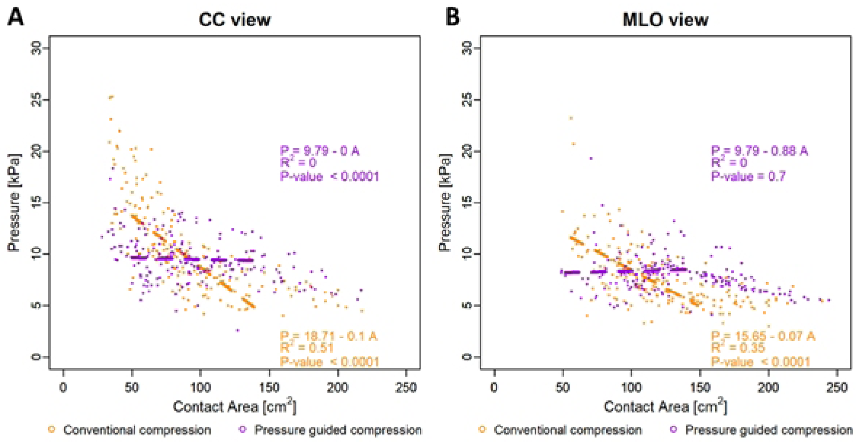


Figure 2. Compression force as a function of breast contact area for individual mammographic examinations during the conventional way of working (orange) and during pressure-based compression (purple) for CC (A) and MLO (B) views. Regression lines were added for both the conventional way of working (dashed orange lines) and pressure-based compression (purple dashed lines). For regression analysis, data with contact areas between 50 and 150 cm² (the range in which the paddle operates) were used.



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CONCLUSION

From this preliminary study it was concluded that the overall procedure experience is improved when using the pressure-based flexible paddle in DBT by both the women participants and the technologists. At the same time, compression pressure variability, mean breast thickness, and glandular dose were significantly reduced. When using the pressure-based system in combination with patient-assisted compression a similarly positive effect was seen on compression parameters when compared with the pressure-based system in combination with standard technologist-assisted compression. The use of the pressure-based flexible paddle in combination with patient-assisted compression has the potential to substantially decrease the negative perception of mammography and DBT due to breast compression and to improve the highly desirable continued participation in breast cancer screening programs.

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