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Mammographic compression – A need for mechanical standardization

Woutjan Branderhorst[a,b,*], Jerry E. de Groot[a,1], Ralph Highnam[c,2], Ariane Chan[c,2], Marcela Böhm-Vélez[d,3], Mireille J.M. Broeders[e,f], Gerard J. den Heeten[g,f], Cornelis A. Grimbergen[a,b]

[a] Academic Medical Center, Department of Biomedical Engineering & Physics, P.O. Box 22660, 1100 DD Amsterdam, The Netherlands
[b] Sigmascreening B.V., Meibergdreef 45, 1105 BA Amsterdam, The Netherlands
[c] Volpara Solutions Limited, P.O. Box 24404, Manners St Central, Wellington 6142, New Zealand
[d] Weinstein Imaging Associates, 5850 Centre Avenue, Pittsburgh, PA 15206, United States
[e] Radboud University Medical Center, Department for Health Evidence, P.O. Box 9101, 6500 HB Nijmegen, The Netherlands
[f] LRCB Dutch Reference Center for Screening, P.O. Box 6873, 6503 GJ Nijmegen, The Netherlands
[g] Academic Medical Center, Department of Radiology, P.O. Box 22660, 1100 DD Amsterdam, The Netherlands

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ABSTRACT

Background: A lack of consistent guidelines regarding mammographic compression has led to wide variation in its technical execution. Breast compression is accomplished by means of a compression paddle, resulting in a certain contact area between the paddle and the breast. This procedure is associated with varying levels of discomfort or pain. On current mammography systems, the only mechanical parameter available in estimating the degree of compression is the physical entity of force (daN). Recently, researchers have suggested that pressure (kPa), resulting from a specific force divided by contact area on a breast, might be a more appropriate parameter for standardization. Software has now become available which enables device-independent cross-comparisons of key mammographic metrics, such as applied compression pressure (force divided by contact area), breast density and radiation dose, between patient populations.

Purpose: To compare the current compression practice in mammography between different imaging sites in the Netherlands and the United States from a mechanical point of view, and to investigate whether the compression protocols in these countries can be improved by standardization of pressure (kPa) as an objective mechanical parameter.

Materials and methods: We retrospectively studied the available parameters of a set of 37,518 mammographic compressions (9188 women) from the Dutch national breast cancer screening programme (NL data set) and of another set of 7171 compressions (1851 women) from a breast imaging centre in Pittsburgh, PA (US data set). Both sets were processed using VolparaAnalytics and VolparaDensity to obtain the applied average force, pressure, breast thickness, breast volume, breast density and average glandular dose (AGD) as a function of the size of the contact area between the breast and the paddle.

Results: On average, the forces and pressures applied in the NL data set were significantly higher than in the US data set. The relative standard deviation was larger in the US data set than in the NL data set. Breasts were compressed with a force in the high range of >15 daN for 31.1% and >20 kPa for 12.3% of the NL data set versus, respectively, 1.5% and 1.7% of the US data set. In the low range we encountered compressions with a pressure of <5 daN for 21.1% and <5 kPa for 21.7% of the US data set versus, respectively, 0.05% and 0.6% in the NL data set. Both the average and the standard deviation of the AGD were higher in the US data set.

* Corresponding author at: Academic Medical Center, Department of Biomedical Engineering & Physics, P.O. Box 22660, 1100 DD Amsterdam, The Netherlands. Tel.: +31 020 566 5388.
E-mail addresses: w.branderhorst@amc.nl (W. Branderhorst), jerry.degroot@sigmascreening.com (J.E. de Groot), ralph.highnam@volparasolutions.com (R. Highnam), ariane.chan@volparasolutions.com (A. Chan), marcelabvelez@gmail.com (M. Böhm-Vélez), mireille.broeders@radboudumc.nl (M.J.M. Broeders), g.denheeten@lrcb.nl (G.J. den Heeten), c.a.grimbergen@amc.uva.nl (C.A. Grimbergen).
[1] Tel.: +31 020 566 5388.
[2] Tel.: +64 4 499 6029.
[3] Tel.: +1 412 441 1161.

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Conclusion: (1) Current mammographic breast compression policies lead to a wide range of applied forces and pressures, with large variations both within and between clinical sites. (2) Pressure standardization could decrease variation, improve reproducibility, and reduce the risk of unnecessary pain, unnecessary high radiation doses and inadequate image quality.

1. Introduction

Detection of pathological conditions in mammography depends on the quality of the obtained images. The natural shape of the breast, with thickness varying from the nipple to the chest wall, is an impediment to achieving good homogeneous signal difference-to-noise ratio (SDNR) over the entire breast image. In mammography, the breast is therefore pressed against the breast support on top of the detector using a transparent plastic compression paddle, such that the breast is deformed into a thinner shape with more uniform thickness. This deformation of the breast is referred to as breast compression. When the paddle is pressed against the breast, a contact area develops according to the size and elasticity of the breast. Breast compression results in multiple benefits, including: (1) reduced radiation dose delivered to the breast; (2) better image contrast due to a reduction of scattered radiation; (3) reduced geometric blurring; (4) better fit of the exposure into the dynamic range of the image receptor; (5) reduced overlapping of tissues; and (6) reduced risk of motion blurring [1]. A disadvantage of breast compression is the associated discomfort or pain in a considerable proportion of women [2–4], especially after breast conserving therapy [5]. The often-conflicting goals of minimizing breast thickness versus reducing discomfort for the woman are balanced by the radiographer (also called mammography technologist or breast imager), who decides how much force is to be applied by the paddle.

Quality standards are unclear as to the appropriate amount of compression force to be applied, and only subjective guidelines are mentioned [6–8]. In practice, the distribution of forces applied by the radiographers is often subject to large variation [9,10]. This variation may partly reflect that the radiographers, by observing the contact area, adjust the compression force to the natural variation in breast size and elasticity. Mercer et al. [10] found a trend of applying higher forces to larger breast volumes in their data, but even between women with similar breast volumes the variation was large. Recent studies also found the applied compression force to be more dependent on the individual radiographer than on the woman subjected to compression [10,11].

Variation in applied compression that is caused by differences in the methods employed by radiographers is not desirable, because it suggests unwanted variation in standard of care, and undermines the consistency and reproducibility of the imaging procedure. This leads to unpredictable differences in image SDNR, radiation dose, and patient experience, between and within women. Radiographer-induced variations in the pain experienced by patients should also be minimized, because even a single bad experience can adversely influence a woman's acceptation of mammography, and may lead to decreased compliance in breast screening programmes [3,12].

A major impediment for standardization and quality control of compression is the lack of specific, objective compression indicators that can help the radiographers to decrease the variability and to improve the predictability and standardization of the compression procedure. In current mammography systems, the only mechanical compression parameters that are objectively measured and displayed real-time are compression force and breast thickness (with only the value measured during X-ray exposure being stored in the DICOM header). Standardization based on these two parameters is complicated because the variation to be reduced is also determined by individual differences in breast size and elasticity. Recently, it has been suggested that pressure (force divided by contact area) might be a better parameter to standardize compression [13,14] (in this issue).

Software has recently become available (VolparaAnalytics), which is able to retrospectively estimate the contact area (A) between the breast and the compression paddle. As the compression force (F) is reported in the DICOM header, this opens up the possibility to estimate the average pressure (P) on the breast by calculating $P = F/A$. In practice, given a certain applied force, the size of the contact area is determined by the size and the elasticity of the breast. Consequently, as a result of the division of force by contact area, pressure is a measure for compression that is independent of breast size and elasticity. Using the contact area measurements, it should be possible to determine whether and how consistently the compression is adjusted to breast size and elasticity.

The purpose of this study is to compare the current compression practice in mammography between an imaging site in the United States (US) and two imaging sites in the Netherlands from a mechanical point of view, and to investigate whether the compression protocols in these countries can be improved by standardization of pressure as proposed in [13,14] (in this issue). Objective mechanical standardization may be an important step towards an individualized, less painful and more reproducible compression procedure in mammography and potentially, in the future, breast tomosynthesis.

2. Methods

In this study we used anonymized quantitative data which, because they cannot be traced back to the actual person, may be used freely for secondary analyses in both the Netherlands and the United States.

2.1. Subjects

We retrospectively reviewed the available parameters of a set of 37,969 mammographic compressions (9188 women) obtained from the Dutch national breast cancer screening programme [15] (the NL data set) and of another set of 7416 compressions (1851 women) from a breast imaging centre in Pittsburgh, PA (the US data set). The NL data set, acquired between May 2012 and September 2013, was obtained from women aged 50–75 years that were all asymptomatic. The US data set, obtained between January 2014 and March 2014, contains both screening and diagnostic mammograms of women in the same age range. Both sets included only cranio-caudal (CC) and medio-lateral oblique (MLO) projections. At both sites, all mammograms of women aged 50–75 years recorded during the stated time periods were included.

The images in the NL data set were acquired at two sites (63.7% and 36.3%) using digital mammography systems of the same type (Hologic Selenia). The images in the US data set were acquired by 5 digital systems of two different types: Hologic Selenia Dimensions (62.7%) and GE Senographe Essential (37.3%). Because the data sets were large and acquired by a large number of radiographers (at least 14 in the Netherlands and 10 in Pittsburgh) we assume that each