Mammographic compression - a need for mechanical standardization

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Aims and objectives

Breast compression is necessary in mammography. It results in multiple benefits, including:

- More homogeneous thickness
- Less scatter
- Better tissue spreading
- Less dose
- Less image blurring

However, a number of problems are related to breast compression:

- Many women consider it painful [1,2]
- There are no quantitative guidelines on the amount of compression force to be applied [3,4].
- The distribution of forces applied by the radiographers is often subject to large variation [5,6]
- Standardization of the applied force 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 might be a better parameter to standardize compression [7,8]. Pressure is defined as force divided by contact area, and can be very different between breasts even when the applied force is the same (Fig. 1).
**Fig. 1**: Video captures of two compressed breasts seen from above with the same force applied to them, illustrating why the physical experience of having a certain force applied to the breast can be very different between women. Light comes from the side, so the dark area is the contact area between the breast and the paddle. The contact area is more than twice as big on the left image. As a result, the pressure, which is the force divided by the area, is more than twice as high on the right image: 21 versus 9 kPa.

**References**: Biomedical Engineering & Physics, Academic Medical Center Amsterdam - Amsterdam/NL

In current mammography systems, the only mechanical compression parameters that are objectively measured and displayed real-time are compression force and breast thickness. As a result, the distribution of applied pressures in current daily practice is unknown. Software has recently become available (VolparaAnalytics), which is able to retrospectively estimate the average pressure on the breast.

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, with regard to both force and pressure, and to investigate whether
the compression protocols in these countries can be improved by standardization of pressure.

**Methods and materials**

We retrospectively studied the available parameters of 37,518 mammographic compressions (9188 women) from the Dutch national breast cancer screening program (NL data set) and of 7171 compressions (1851 women) from a breast imaging centre in Pittsburgh, PA (US data set). The NL data set was obtained from asymptomatic women only, whereas the US data set contains both screening and diagnostic mammograms. Both sets were obtained from women aged 50-75 years. Only cranio-caudal (CC) and medio-lateral oblique (MLO) projections were included.

All mammograms 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.

The compression behaviour of the radiographers was visualized using scatter plots and by plotting line graphs of average and standard deviation for the variables force, pressure, breast thickness, AGD, breast volume and breast density for each of the two data sets. Because of the large number of overlapping data points, the colour of the points in the scatter plots was varied as a function of the local point density, using a linear colour scale.

Statistics were calculated using R (version 3.1, R Foundation for Statistical Computing, Vienna, Austria). Mann-Whitney U-tests were used to study the overall differences and regression analysis was performed to examine the association between these differences and the size of the contact area.

**Results**
Fig. 2: Scatter plots of applied forces (top) and pressures (bottom) versus contact area in the NL (left) and the US (right) data sets. Each point corresponds to one compression, either CC or MLO. Darker colours denote higher local point density. Large variations in pressure can be observed, even larger than in force, both within and between the NL and the US data sets.

**References:** Eur J Radiol (2014), http://dx.doi.org/10.1016/j.ejrad.2014.12.012

Fig. 2 displays the distributions of applied forces and pressures for the NL and US data sets. The force distributions in both data sets are characterized by large variation, and the variation in the pressure distributions is even larger. The forces (means ± standard deviation (SD)) are 13.8 ± 2.7 daN in the NL data set versus 7.4 ± 3.1 daN in the US data set (p < .001). The pressures are, respectively, 13.7 ± 5.9 kPa and 8.1 ± 4.1 kPa (p < .001). The relative standard deviation was larger in the US data set than in the NL data set; respectively 41.9 % versus 19.6 % for the force, and 50.6 % versus 43.1 % for the pressure.
Fig. 3: Compression force (A) and pressure (B): comparison of mean ± one standard deviation between NL and US data sets, in relation to contact area. The plots show similar trends but exercised at significantly different levels.


Fig. 3 shows how the averages and variations in applied force and pressure change with the contact area, providing the additional insight that the average force applied by the radiographers increases with contact area in an approximately linear fashion in both data sets, with almost the same the slope. In other words, the Dutch radiographers seem to employ a strategy similar to that applied in the US clinical site, but starting with a certain offset. Neither of these strategies leads to a standardized pressure. For both data sets, that the smaller the contact area, the higher the average applied pressure and the larger the difference in average pressure between the NL and the US data set.

Fig. 4: Comparing the NL data set with the US data set: breast density (A) and volume (B) versus contact area: mean ± one standard deviation. The almost complete overlap
indicates the similarity of both populations with regard to breast density and breast volume.

**References:** Eur J Radiol (2014), http://dx.doi.org/10.1016/j.ejrad.2014.12.012

Fig. 4 compares the breast density and volume in relation to contact area between the NL and the US data sets. Over the entire range of contact areas, the estimated breast density differs only slightly between the two data sets; on average, 7.02 ± 4.73 % (mean ± SD) in the NL data set versus 7.71 ± 5.82 % in the US data set, p = .0018). No structural differences in breast density and volume that are dependent on contact area appear between the two populations.

![Fig. 4](image)

**Fig. 4:** Comparing breast density and volume in relation to contact area between the NL and US data sets. Over the entire range of contact areas, the estimated breast density differs only slightly between the two data sets; on average, 7.02 ± 4.73 % in the NL data set versus 7.71 ± 5.82 % in the US data set, p = .0018). No structural differences in breast density and volume that are dependent on contact area appear between the two populations.

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Fig. 5 compares the breast density and volume in relation to contact area between the NL and US data sets. Over the entire range of contact areas, the estimated breast density differs only slightly between the two data sets; on average, 7.02 ± 4.73 % (mean ± SD) in the NL data set versus 7.71 ± 5.82 % in the US data set, p = .0018). No structural differences in breast density and volume that are dependent on contact area appear between the two populations.

**References:** Eur J Radiol (2014), http://dx.doi.org/10.1016/j.ejrad.2014.12.012

Fig. 5 shows that, despite the differences in applied force and pressure, the mean breast thickness is also similar between the data sets. On average, the measured breast thickness was 0.8 mm (1.3 %) higher in the NL data set (60.7 ± 11.8 mm (mean ± SD) versus 59.9 ± 13.9 mm in the US data set, p = .0013). The standard deviation was 18 % larger in the US data. The US data set had a higher mean AGD value (1.83 ± 0.73 mGy) and a larger standard deviation compared to the NL data set (1.54 ± 0.35 mGy, p < .001).

**Conclusion**
Besides differences in the mean force and pressure of both populations, this comparison shows a large variation in both data sets with many extreme pressures resulting from the lack of any mechanical standardization. For the individual woman, the amount of applied pressure is currently almost unpredictable.

Standardization, potentially based on pressure rather than force, would:

1. make the procedure and the resulting image more reproducible between and within women
2. avoid extremely high pressure outliers causing unnecessary pain
3. avoid very low pressure outliers to reduce the radiation dose related to insufficient compression and the risk of insufficient image quality
4. enhance quality control of mechanical compression

Personal information

References