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Development of a phantom to test fully automated breast density software – A work in progress

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ABSTRACT

Objectives: Mammographic density (MD) is an independent risk factor for breast cancer and may have a future role for stratified screening. Automated software can estimate MD but the relationship between breast thickness reduction and MD is not fully understood. Our aim is to develop a deformable breast phantom to assess automated density software and the impact of breast thickness reduction on MD.
Methods: Several different configurations of poly vinyl alcohol (PVAL) phantoms were created. Three methods were used to estimate their density. Raw image data of mammographic images were processed using Volpara to estimate volumetric breast density (VBD%); Hounsfield units (HU) were measured on CT images; and physical density (g/cm^3) was calculated using a formula involving mass and volume. Phantom volume versus contact area and phantom volume versus phantom thickness was compared to values of real breasts.
Results: Volpara recognized all deformable phantoms as female breasts. However, reducing the phantom thickness caused a change in phantom density and the phantoms were not able to tolerate same level of compression and thickness reduction experienced by female breasts during mammography.
Conclusion: Our results are promising as all phantoms resulted in valid data for automated breast density measurement. Further work should be conducted on PVAL and other materials to produce deformable phantoms that mimic female breast structure and density with the ability of being compressed to the same level as female breasts.
Advances in knowledge: We are the first group to have produced deformable phantoms that are recognized as breasts by Volpara software.

Introduction

Mammographic density (MD) is the radiographic density of the breast on a mammogram, reflecting the amount of radiodense (parenchymal and connective tissue) and radiolucent tissue (fat) present.[1] MD has been shown to be a strong risk factor for breast cancer, where the risk of developing breast cancer is three to six times greater for women with the densest breast compared to those with a fatty breast.[1,2] MD is thus considered as an important factor to determine screening intervals and additional imaging, where women with a high MD may benefit from shorter intervals or additional imaging, such as ultrasound or magnetic resonance.[3]

There are several methods to measure MD, where the most common is visual assessment using the Breast Imaging Reporting and Data System (BIRADS) scale[4] of the American College of Radiology. This visual assessment is prone to inter- and intra-reader variability,[5] which has led to the development of automated systems to provide an objective assessment of MD. The Volpara software[6] (*Matakina Technology Limited, Wellington, New Zealand*) is a fully automated software that analyses digital mammograms to

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obtain the total volume of breast tissue (cm^3), the volume of fibroglandular tissue (cm^3), and calculates the ratio between these volumes to obtain the volume of dense tissue in the breast, known as the volumetric breast density (VBD%).[7]

Breast compression with subsequent thickness reduction in mammography improves image quality and reduces radiation dose.[8] Currently, there are no UK guidelines for optimal compression, other than it should not exceed 200 Newton.[9] This lack of guidance is compounded by a large variation in applied compression forces between practitioners and screening sites.[10] Deformable breast phantoms of varying density are necessary to test the effect of breast compression and thickness reduction on MD; however, such phantoms are currently not available.

The aim of this study was to develop and assess a range of deformable breast phantoms simulating different tissue compositions and densities for assessing fully automated breast density assessment software (Volpara), that later could be used to investigate the impact of breast thickness reduction on MD.

Methods and materials

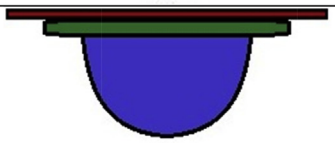
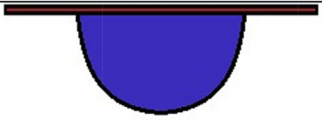
A pilot study was conducted to enable the creation of a range of breast phantoms with different configurations of tissue components and densities, and further to test their ability to withstand compression with subsequent thickness reduction. The pilot study is described elsewhere.[11]

In this study we developed breast phantoms with four different configurations (Table 1). The amount of Poly-Vinyl alcohol (PVAL) and the number of freeze-thaw cycles (FTC) that the PVAL solution was exposed to, was based on literature which outlined the Hounsfield Units (HU) and Young's Modulus (YM) of female breast.[12–15] Freeze and thawing of the PVAL solution is necessary to form molecular crosslinking to change the solution into a gel. Stiffer gel can be created through more FTCs; higher density of the gel can be achieved by using a higher concentration of PVAL and/or introducing a doping agent of a higher density (e.g. radiopaque contrast agent). All phantoms comprised of three primary components; a wooden board to simulate the chest wall, PVAL to simulate breast fatty tissue (7.5% PVAL, 1-FTC), and latex to simulate skin. The four breast phantoms also contained different configurations of simulated glandular tissue (GT (glandular tissue); 10% PVAL + 1.75 ml of Optiray 320 (*Covidien, Dublin, Ireland*), 2-FTC), and simulated pectoral muscle (PM; 10% PVAL, 2-FTC). A schematic diagram is illustrated in Table 1.

Density measurements

Three experiments were used to estimate density of the phantoms: (i), the raw data of mammographic images were analysed in the Volpara software to obtain the VBD%; (ii), HU values were measured on CT images; and (iii), physical density (g/cm^3) was calculated using a formula with mass and volume. The phantoms

Table 1
The characteristics of the PVAL phantoms used in the main experiment; containing different configurations of chest wall (red), pectoral muscle (green), fatty tissue (blue), glandular tissue (yellow) and skin.

Study phantom	Breast Shaped Phantom Requirements					Schematic diagram
	Chest Wall (wooden board, red)	Pectoral Muscle (10% PVAL, 2-FTC, green)	Fatty Tissue (7.5% PVAL, 1-FTC, blue)	Glandular Tissue* (10% PVAL & contrast agent, 2-FTC, yellow)	Skin (latex)	
B7.5-ALL*	Y	Y	Y	Y	Y	
B7.5-NO GT	Y	Y	Y		Y	
B7.5-NO PM	Y		Y	Y	Y	
B7.5-NO GT/PM	Y		Y		Y	

*Optiay 320/ml was used as contrast agent for the glandular tissue (GT) to get the correct ratio with fatty tissue

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