A New Step-Wedge for the Volumetric Measurement of Mammographic Density

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Abstract. The volume of dense breast tissue can be calculated from an x-ray mammogram by imaging a calibrated step-wedge alongside the breast and determining the compressed breast thickness. Previously published work used a step-wedge made of PTFE with a maximum height of 35mm, length 175mm and width 15mm. Although fulfilling all theoretical requirements, it can be difficult to find space on the film for a large step-wedge when examining bigger breasts. Furthermore, the step-wedge is lead-lined, making it heavy and difficult to attach to the bucky. A more compact aluminium step-wedge has been designed to overcome these limitations, and experiments have been carried out on a prototype to evaluate its performance. Initial results show that the maximum and minimum heights of the prototype step-wedge are inadequate to sufficiently cover the range of optical densities within a breast image at the higher and lower exposures required for 6cm and 2cm Perspex (>200mAs and < 40mAs respectively). However, the step increment appears to be satisfactory. Analysis of the mean pixel value and standard deviation within Regions of Interest of varying size and position indicates an optimum step length of 3mm. A new step-wedge has been constructed with an improved specification informed by the evaluation of the prototype.

1 Background

Increased breast density is associated with a higher risk of developing cancer [1, 2, 3, 4]. Various techniques exist for estimating or measuring dense tissue [5, 6, 7, 8, 9, 10]. One such method involving the use of a calibrated step-wedge has been used previously to study women at increased risk of developing cancer [11, 12]. This method, however, suffers from a number of limitations, and we now examine in detail the design considerations for a step-wedge, using a new aluminium prototype for evaluation purposes, and hence develop a specification for a wedge suitable for use in routine clinical practice.

In order to quantify dense breast tissue, a calibrated step-wedge can be imaged alongside the breast, with radio-opaque magnification markers on the compression paddle to enable determination of breast thickness at a series of points. The density at

Susan M. Astley et al. (Eds.): IWDM 2006, LNCS 4046, pp. 1 – 9, 2006.

each pixel in the resulting mammogram is then matched to the equivalent density in the calibrated step-wedge. The corresponding thickness of the step-wedge at this point, combined with breast thickness measurement, allows composition to be uniquely determined at each pixel.

The original step-wedge [13] was constructed of PTFE (polytetrafluoroethylene / *Teflon*). It had 25 steps, each of height 1mm and length 5mm, giving a maximum height of 25mm and a total length of 125mm. The width of all steps was 12mm. It was necessary to shield the sides of the wedge with lead to ensure that only those parts of each step where x-rays have travelled through the whole thickness of the wedge are imaged. The wedge is positioned at the top left-hand corner of the breast support platform (bucky) and is therefore exposed to x-rays traveling at an oblique angle. Without lead shielding the image becomes blurred by x-rays that only pass through part of the wedge, causing the grey level to vary across each step.

It was found that at the higher exposure factors required for greater breast thickness and density, the optical density of the step-wedge on the image increased to the extent that the 25mm step-wedge did not adequately cover the range of optical densities expected within the breast [12]. An additional 10 steps were added increasing the overall height to 35mm and the length to 175mm. A further limitation was that when placed near the edge of a 24×30cm breast support platform, the distance from the point directly below the x-ray source increased, causing the x-rays pass through the step-wedge at a more oblique angle and reducing the usable width. The width of the 35mm step-wedge was therefore increased to 15mm, giving a usable width of 4mm at height 35mm.

Despite fulfilling the theoretical requirements to enable calibration, in practice the 35mm step-wedge was sometimes too big to fit alongside larger breasts and the lead lining made it a relatively heavy, unwieldy device that could not easily be attached to the bucky [14]. A further limitation of the PTFE wedge was that analysis required accurate identification of step positions in the digital image. Typically, one end of the wedge was overexposed and the other underexposed, so finding the ends accurately was non-trivial.

2 Method

In order to optimize the specification for a new step-wedge that will overcome the limitations shown by the PTFE wedge, a prototype wedge made of aluminium has been constructed and evaluated.

2.1 Step-Wedge Material

PTFE was used previously because it has a similar mass attenuation coefficient to breast tissue, but a higher density than most plastics, allowing a larger range of attenuation to be achieved without requiring too great a thickness. PTFE would also minimise beam hardening effects, which could have been significant in the original analysis method. However, the calibration method is now much less sensitive to these effects and enables higher atomic number materials to be considered.