Quantification of optical density and latitude requirements in mammography

S Meeson [1], K C Young [1], M L Ramsdale [1], M G Wallis [2] and J Cooke [3]

NHS Breast Screening Programme

[1] NCCPM, Royal Surrey County Hospital, Guildford. [2] Coventry Breast Screening Centre. [3] Jarvis Breast Screening Centre, Guildford.

Introduction

Objective : to develop tools to quantitatively assess image quality in mammograms.
Ultimate aim : to optimise imaging procedures and improve cancer detection.
Two studies are presented, which investigate the requirements of film optical density and latitude in screening mammography.

Study 1 - Optical density and latitude measurments

• 120 Mammograms (92 oblique views and 28 cranio-caudal views) of 46 women recorded on a single day of screening were studied.
• X-ray unit was an IGE 600 TS SENIX, the film / screen combination was Sterling Microvision C / detail screen. Films were processed using a Sterling T6 processor operating at 34°C on extended cycle.
• Films were digitised (at 110 μm resolution) using a Lumisys 150HR laser digitiser, together with density calibration strips to facilitate the conversion from image pixel value to optical density (OD).

Figure 1 : Mammogram showing the ROIs and the skin line.

Labels: Pectoral muscle, Skin line, Main Breast, Skin edge region, "Black part" of film

• Each image was divided into three mutually exclusive regions of interest (ROI), representing the pectoral muscle, skin edge, and the main breast region (Figure 1).
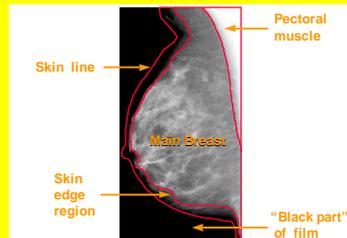
• Images were median filtered before a threshold technique was used to select the ROI.
• Measurements included the maximum, minimum, and mean OD for each ROI on each image.
• The relative exposures of the film ($\log_{10}E$) corresponding to each film OD were calculated using the measured characteristic curve for the film screen system (Figure 2).
• The dynamic range of $\log_{10}(E)$ in the main breast ROI (DR) was then calculated for each mammogram :

$$DR = \log_{10} E(\text{maximum OD in the main breast ROI}) - \log_{10} E(\text{minimum OD in the main breast ROI})$$

• The DRmax defined below and shown in Figure 2 represents the DR for an ideal OD range, and from which it is possible to approximate how many mammograms may be imaged in an ideal manner with this system.

$$DR_{max} = \log_{10} E(\text{upper OD limit}) - \log_{10} E(\text{lower OD limit})$$

Figure 2 : Characteristic curve.
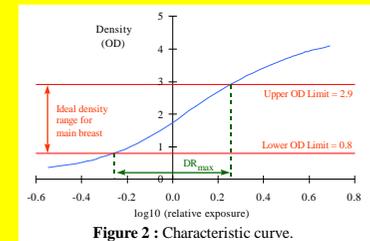
Two radiologists independently assessed different parts of each film for quality, grading the OD of glandular tissue, adipose tissue, and pectoral muscle on a seven point scale from very high to very low. The mid-point (OK) representing the ideal.

Study 2 - Skin edge perception

The entire skin edge region cannot be seen on some mammograms. A new film has been developed by Agfa, to attempt to impove skin edge visualisation.
 – HDR (High Dynamic Range).
 – Second emulsion layer to modify the gradient of characteristic curve at OD > 2.8.
• Qualitative and quantitative comparison of new Agfa HDR film and Fuji UM film was performed to assess the consequence of the modified characteristic curve.
 – 216 mammograms (108 oblique views and 108 cranio-caudal views) from 54 women.
 – For each view on each woman one breast was imaged using the current Fuji UM film and the other using the new Agfa HDR film.
 – X-ray set used was an IGE DMR operating at a manually selected 27 kV.
 – AEC system was adjusted to achieve a target density of 1.7 ± 0.1 on QC films for both film types.
• Radiologist graded appearance of skin edge as either :
 – *dark*, if the skin edge was too dark to see the skin line
 – *just visible*, if the skin line could just be seen
 – *visible*, if the whole skin edge region could be seen.
Films were viewed in low ambient light conditions on a masked light box.
• Maximum OD at the skin edge was measured in each film using a spot densitometer.
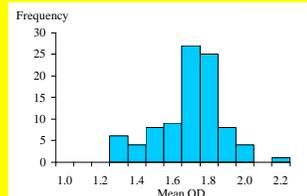• OD of the "black part" of each film (Figure 1) was also measured.

Results - Study 1

Figure 3: Histogram showing the range of mean OD in the main breast ROI (oblique views only).
• Mean OD ranged from 1.25 to 2.24 with an average of 1.75.
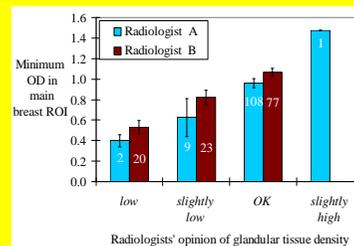• Corresponding OD for blocks of PMMA exposed on the system was 1.53.

Figure 4: Relationship between minimum OD in the main breast and opinion of glandular tissue density.
• Films graded as having *low* or *slightly low* glandular densities, had a minimum OD below about 0.8.
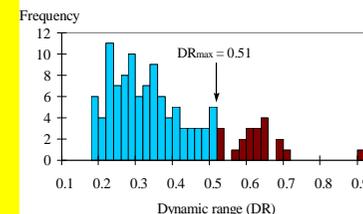• Similarly tissue density was graded as *slightly high* or *high* above an OD of 2.9.

Figure 5: Histogram showing the distribution of mammogram DR.
• In this study the lower and upper OD limits of 0.8 and 2.9 correspond to a DRmax of 0.51.
• In 17 % of all the mammograms the main breast region had a DR greater than 0.51.
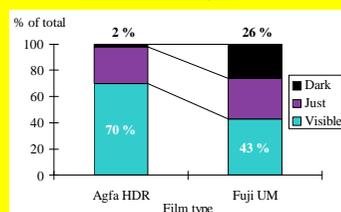
Results - Study 2

Figure 6: Percentage of Agfa and Fuji films with *visible*, *just visible*, and *dark* skin edges.
• Significantly more *visible* skin edges with Agfa HDR film than Fuji UM film.
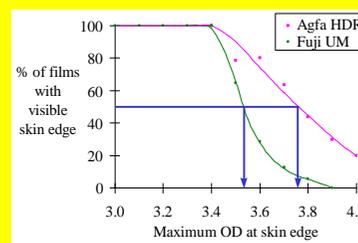• 2 % of Agfa films had *dark* skin edges compared to 26 % of the Fuji films.

Figure 7: The percentage of films with *visible* skin edges at each OD is shown.
• 50 % of skin edges are still *visible* at an OD approaching 3.8 with the Agfa film, about 0.2 OD higher than with the Fuji film.
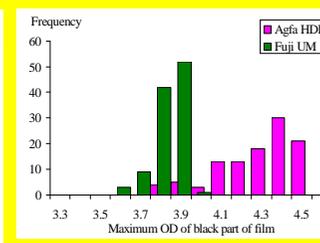

Figure 8: Histogram showing the ODs of the "black part" of the film.
• Black part of film OD approximately 0.5 OD higher in the Agfa film.
• Agfa and Fuji skin edge OD similar at 3.6 ± 0.3.

CONCLUSIONS

Study 1

• Study has demonstrated how film OD and latitude requirements for clinical mammograms can be assessed quantitatively.
• Where film ODs for all tissues in the main breast region were within the range 0.8 to 2.9 even relatively dense glandular tissue could be adequately displayed.
• An analysis of the latitude requirements showed that about 17% of the breasts could not be ideally displayed with the high contrast system used.
• The current target density of 1.6 (including base + fog) appeared suitable for this imaging system.

Study 2

• Skin edges were better visualised with the Agfa HDR film.
• Ideally for good skin edge visualisation :
 – OD of the skin edge should be < about 3.8.
 – There should be a large difference between the OD of the skin edge and the OD of the "black part" of the film near the skin line.