Optical density and latitude requirements of high contrast mammography films

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Introduction

Fuji AD-M and Kodak min-R 2000 film screen combinations produce higher contrast mammograms than with film types previously used. The objective of this study was to evaluate the implications of using these film screen combinations in the UK NHS Breast Screening Programme (NHSBSP). For comparison the Fuji UM-MA (HC) film was also investigated since it has a lower contrast than both Fuji AD-M and Kodak min-R 2000, and is still in widespread use in the NHSBSP.

Quantitative Film Assessment

- The film screen systems evaluated clinically are detailed in Table 1.
- Clinical films were digitised at 210 µm resolution, using a laser scanner. A pixel value to optical density (OD) calibration was used to create images with pixels in OD units.
- Images were analysed using the regions of interest (ROI) shown in Figure 1. Macro programmes selected the ROI, and performed image analysis. Measurements included the maximum, minimum and mean OD in each ROI.
- To compare the characteristic curves of the three film types, an Aluminium step-wedge was imaged at 28 kV with each film.
- The latitude available in the lower half of the characteristic curves (L_{lower}) can be used to estimate what percentage of films can be expected to optimally display areas of dense glandular tissue. The lower latitude available in each film screen system was calculated using Equation (1), and the lower dynamic range for each mammogram (DR_l) was calculated using Equation (2).

(1) $L_{lower} = \log_{10} E(\text{mean OD of } 1.8) - \log_{10} E(\text{suggested minimum OD limit})$

(2) $DR_l = \log_{10} E(\text{mean OD in the main breast ROI}) - \log_{10} E(\text{minimum OD in the main breast ROI})$

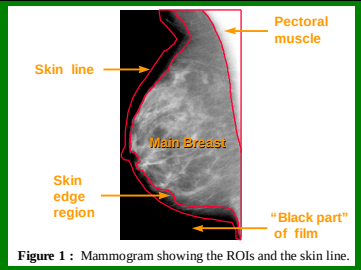

Figure 1 : Mammogram showing the ROIs and the skin line.

Film	Fuji AD-M	Kodak min-R 2000
Screen	Fuji AD-M fine	Kodak min-R 2000
No. of women	42	45
No. of films	116	122
MLO views	84	89
CC views	32	33
X-ray set	Siemens Mammomat 2S	GE Senographe 600TS
kV	28	28
		30 for *large* breasts
Processor	Fuji FPM 2800	Kodak M35M
Chemicals	Photosol	Kodak RP X-Omat EX

Table 1 : Film screen systems evaluated clinically.

Visual Grading Analysis

Two radiologists independently assessed the different parts of each film for quality. The OD of glandular tissue was graded on a seven point scale from *very high* to *very low*. The mid-point (*OK*) represented the ideal.

Results of Clinical Film Analysis

Grading of appearance of glandular tissue density	Minimum OD	
	Fuji AD-M	Kodak min-R 2000
Low	0.38 ± 0.04	0.62 ± 0.08
Slightly low	0.46 ± 0.05	0.76 ± 0.07
OK	0.74 ± 0.04	0.96 ± 0.03
Slightly high		0.92 ± 0.06

Table 2 : Mean minimum OD in the main breast ROI for each grade of glandular tissue visualisation. (errors represent ± 2 standard errors in the mean.)

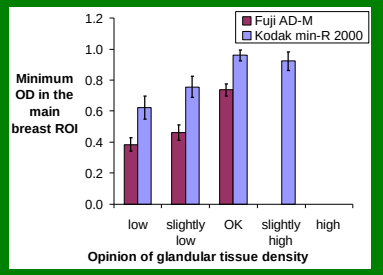

Figure 5 : Relationship between minimum OD and the radiologists' opinion of glandular tissue density.

- Figure 5 illustrates that for each grade of glandular tissue density the Fuji AD-M film had lower mean minimum ODs than the Kodak min-R 2000. For both film types, the mean minimum ODs were lower for films that were judged to have *low* or *slightly low* glandular tissue densities than those whose glandular tissue densities were judged to be *OK*.
- The mean minimum ODs for each grade of glandular tissue visualisation are listed in Table 2 for both imaging systems. The mean minimum ODs for Fuji AD-M were of the order of 0.2 OD lower than for Kodak min-R 2000.
- 95 % of the films graded as having areas of *low* glandular tissue density had a minimum OD below approximately 0.8 for Kodak min-R 2000 and below approximately 0.6 for Fuji AD-M.
- In a similar test to assess the acceptable maximum density in the main breast region, tissue density was generally graded as *slightly high* or *high* above an OD of 2.9 for Kodak min-R 2000, but there was no clear relationship for Fuji AD-M.

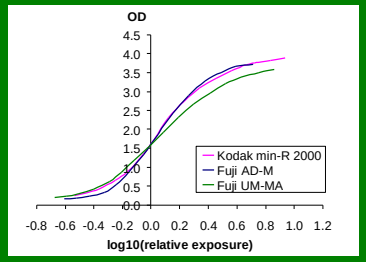

Figure 2 : Characteristic curves

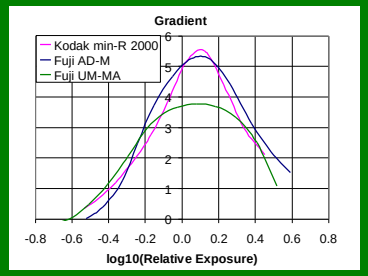

Figure 3 : Gradients of the characteristic curves

Results of Physical Measurements

- Figure 2 shows that both the Fuji AD-M and the Kodak min-R 2000 films have higher contrast than the Fuji UM-MA film. The average gradient between an OD of 1.0 and 2.0 above base plus fog was 3.67 for Fuji UM-MA, 5.15 for Fuji AD-M, and 5.21 for the Kodak min-R 2000.
- The main difference between the two higher contrast curves is in the lower half, resulting in average gradients between an OD of 0.25 and 2.00 above base plus fog of 4.38 for Fuji AD-M and 3.77 for Kodak min-R 2000 (and 3.10 for Fuji UM-MA).

- Figure 3 illustrates the relationship between exposure and film gradient. The difference in gradients between Fuji UM-MA and the other two films is apparent across the range of $\log_{10}E$ corresponding to the mid-range of ODs. The gradient of the Fuji AD-M film crosses-over from above to below that of the other two films for exposures between approximately –0.2 and –0.3 ($\log_{10}E$).

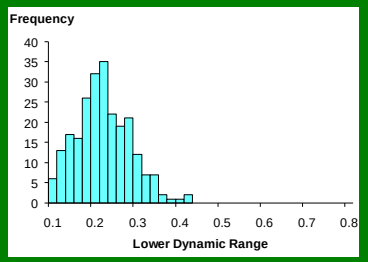

Figure 4 : Histogram showing the distribution of lower dynamic range.

- Figure 4 shows the distribution of DR_l for all the clinical films. The L_{lower} for Fuji UM-MA was 0.28, for Fuji AD-M was 0.26, and for Kodak min-R 2000 was 0.22. In 18 % of the Fuji UM-MA mammograms the DR_l was greater than the L_{lower}, compared to 26 % of the mammograms for the L_{lower} of Fuji AD-M, and 44 % of the mammograms for the L_{lower} of Kodak min-R 2000.

Discussion

- The Fuji AD-M film generally had the highest film gradient over the mid-range of exposures. However as shown in Figure 3 the gradient fell very rapidly at lower exposures corresponding to OD of less than approximately 0.5 (equivalent to a $\log_{10}E$ of -0.3). At these exposures the film contrast was less than that of the other film types.
- The suggested minimum OD limits for ideal glandular tissue visualisation are 0.8 for Kodak min-R 2000 and 0.6 for Fuji AD-M. These limits are based on radiologists' opinions, but appear to be related to the lower film contrast below these limits. In earlier studies a minimum OD limit of 0.8 was suggested for Fuji UM-MA and Sterling Microvision C films.
- L_{lower} was calculated as a measure of the dynamic range from mid to low OD. Both Fuji AD-M and Kodak min-R 2000 have smaller L_{lower} than the Fuji UM-MA film indicating narrower latitude. The percentages of films with a DR_l greater than the corresponding L_{lower} was smallest for the Fuji UM-MA, the film with the lowest contrast. This film type will therefore have the fewest films that cannot be optimally imaged at any exposure. Therefore screening centres using either Fuji AD-M or Kodak min-R 2000 films are likely to have more mammograms in which the *dense* glandular tissue may be judged to be too light.

Conclusions

- The main breast regions of the mammograms produced using both Fuji AD-M and Kodak min-R 2000 were satisfactorily visualised when breast tissues were displayed with optical densities above approximately 0.6 and 0.8 respectively.
- Although the use of modern very high contrast films improves the appearance of most mammograms, the problems of visualising breasts with *dense* glandular tissue using such high contrast films mean that unless there is a change in imaging technique, there may be an increase in the number of films which have excessive contrast and need to be repeated.