Chapter 7

Application of Radiographic Contrast-Enhancement Masks in Digital Radiography

The development of radiographic contrast-enhancement masks (RCMs), to be applied to digital radiographic (DR) images, was detailed in the previous chapter. RCMs can be categorised into several sub-types. The sub-types of RCM that were developed as part of this research are wedge filters and the boomerang filters. A further sub-type not yet fully evaluated is the chest RCM.

RCMs were developed to assist in overcoming difficulties in viewing DR images. Large differences in attenuation and thickness of anatomical regions within an image cause large optical density (OD) differences in the DR images. Examples of anatomical regions where such large OD differences exist are shown in Table 7.1.

In this project RCMs were applied to all these regions listed in Table 7.1 with the exception of the chest region. Examples of images with and without RCM are provided and discussed in this chapter. Appropriate and inappropriate use of factors that alter RCMs is also discussed, together with a comparison of RCM and other techniques used for dynamic range control. Specifically applied digital RCMs enhance the displayed contrast in specific areas of the image, whilst leaving other areas unaffected. The overall effect is to reduce the dynamic range of the DR image while maintaining high subject contrast within the image.

The images displayed in this chapter were Digital Imaging and Communications in Medicine (DICOM) DR image format and have been converted to Joint Photographic Expert Group (JPEG) format for display purposes. All images displayed in this chapter have been globally adjusted for brightness and contrast. This process and the conversion to JPEG format were undertaken using the viewing software eFilm, version 1.4.1 (eFilm Medical Imaging System; http://www.eFilm.net). eFilm uses a linear look-up table (LUT) of Window Width (WW) and Window Level (WL) functions to alter displayed contrast and brightness respectively. The use of WW and WL was discussed in Chapter 5.

Table 7.1 Examples of anatomical regions where large optical density differences exist (Ballinger, 1991)

Anatomical Region	**Explanation of Wide Dynamic Range**
chest	large attenuation differences between the air filled lungs and the thoracic spine
thoracic spine	large anatomical thickness differences between the superior and inferior portions of the thoracic spine
shoulder	large anatomical thickness differences between the edges of the shoulder and the chest region within the image
facial bone	lateral image required to display both soft tissue and bony anatomy
cervical spine	lateral image required to display both the cervical vertebra and the cervico-thoracic junction; large attenuating difference between the cervical vertebra and the cervico-thoracic junction regions
cervical spine	lateral image required to display both soft tissue and bony anatomy
thoraco-lumbar spine	lateral image required to display both the thoracic spine and the lumbar spine
hip / neck of femur	cross-table lateral used; large attenuating difference between the pelvic region and the neck of femur within the image
femur	large anatomical thickness differences between the superior and inferior regions of the femur
feet	anatomical thickness differences between the tarsal region and the metatarsal/phalanges of the foot
hands	lateral image required to display both the metacarpals and the phalanges
abdomen	horizontal ray required to show air/fluid differences; attenuation differences further increased when barium is introduced to outline the gut

7.1 Boomerang RCMs

Boomerang RCMs were developed specifically for use with shoulder DR images. Figures 7.1a & b show a comparison of shoulder DR images; the original image and the same image following application of a boomerang RCM.

The original image, Figure 7.1a, has low radiographic contrast designed to show all optical densities within the image. Figure 7.1b has had an appropriate boomerang RCM applied. The user selectable factors of the boomerang RCM are shown in Table 7.2.

Table 7.2 User selectable factors of boomerang RCM – right shoulder (Figure 7.1b)

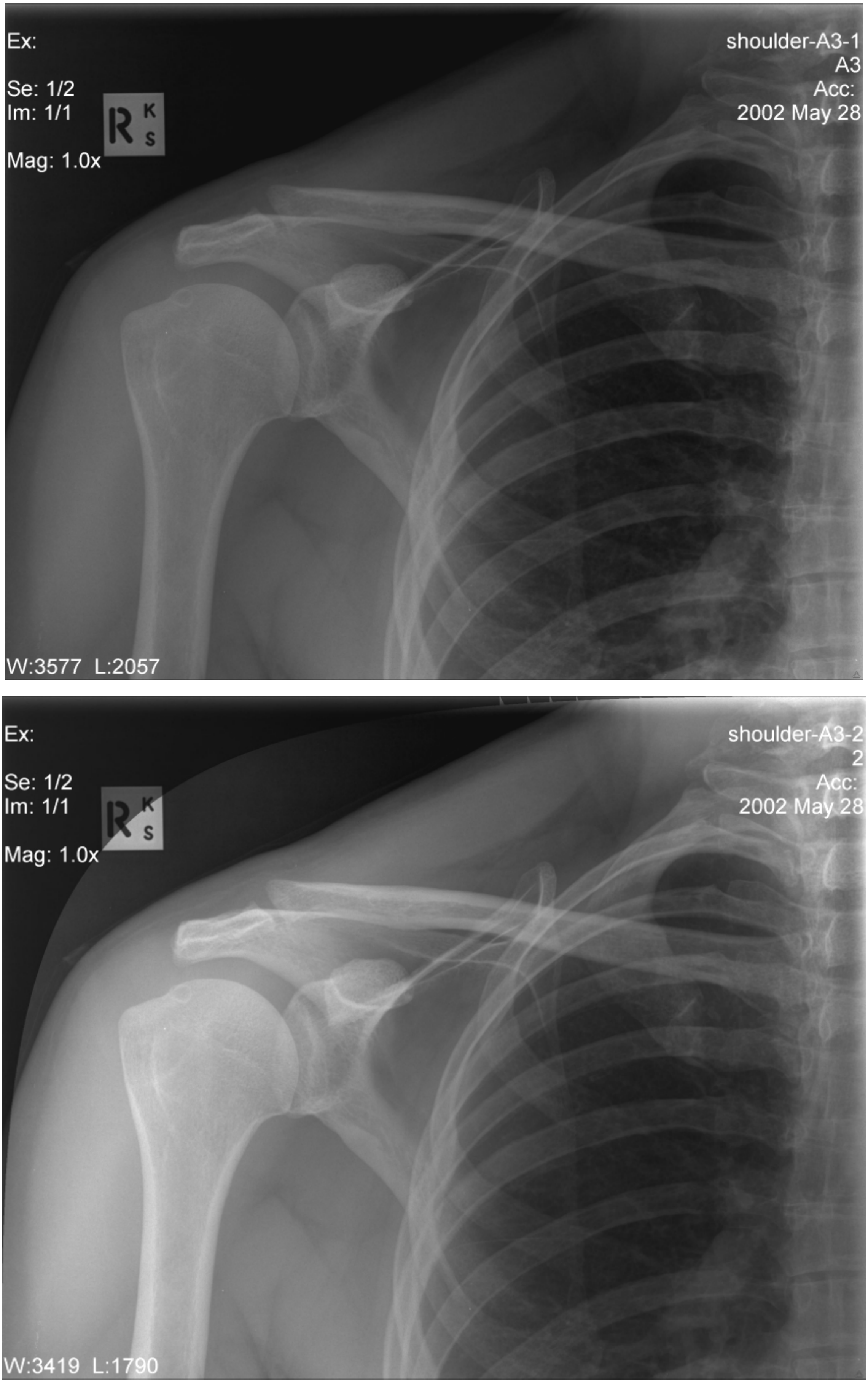
User Selectable Factors (Figure 7.1b)
R or L shoulder: R
plan view curve (*q*): 2.7
profile width (*s*): 3.0
profile height: 2.5

The image in Figure 7.1b shows improved radiographic contrast around the periphery of the shoulder (humerus, acromion, A/C joint and associated soft tissue) while still maintaining high radiographic contrast in the chest/ribs and scapula regions of the image. The application of an appropriate RCM has allowed the entire image to be optimised with high radiographic contrast while still displaying all the optical densities within the image.

eFilm software displays the WW and WL values at the bottom left of each image as W and L values respectively. The W value of the original image (Figure 7.1a) is 3,577 and the W value of the RCM image is 3,419. This indicates that the RCM image is displayed with a slightly higher radiographic contrast. This assumption would be correct if both images were identical in their pixel values. However, the

RCM algorithm discussed in Chapter 6 alters the pixel values in a manner that prevents direct comparison with the pixel values of the original image.

An artefact is created and displayed when using the boomerang RCM. This is seen as a curved line in Figure 7.1b starting at the bottom left corner of the image, extending towards the top left corner and ending in the top right corner of the image. The artefactual line is external to the shoulder anatomy. For this image, the boomerang RCM factors were adjusted to ensure that the artefact would not appear over the anatomy.



a

b

Figure 7.1 Comparison of boomerang RCM

a. Original image
b. RCM image: Factors of q = 2.7, s = 3.0 and height = 2.5

7.2 Factor Selection for Boomerang RCMs

Users select the factors that control the shape and profile of the boomerang RCM so as to optimise the appearance of the DR shoulder image. In the clinical environment, it is expected that this would be the role of the radiographer. Inappropriate selection of factors can degrade the appearance of the image. An example of this is shown in Figure 7.2. In this example the factors were the same as for the RCM in Figure 7.1b except that the profile width was 1.0.

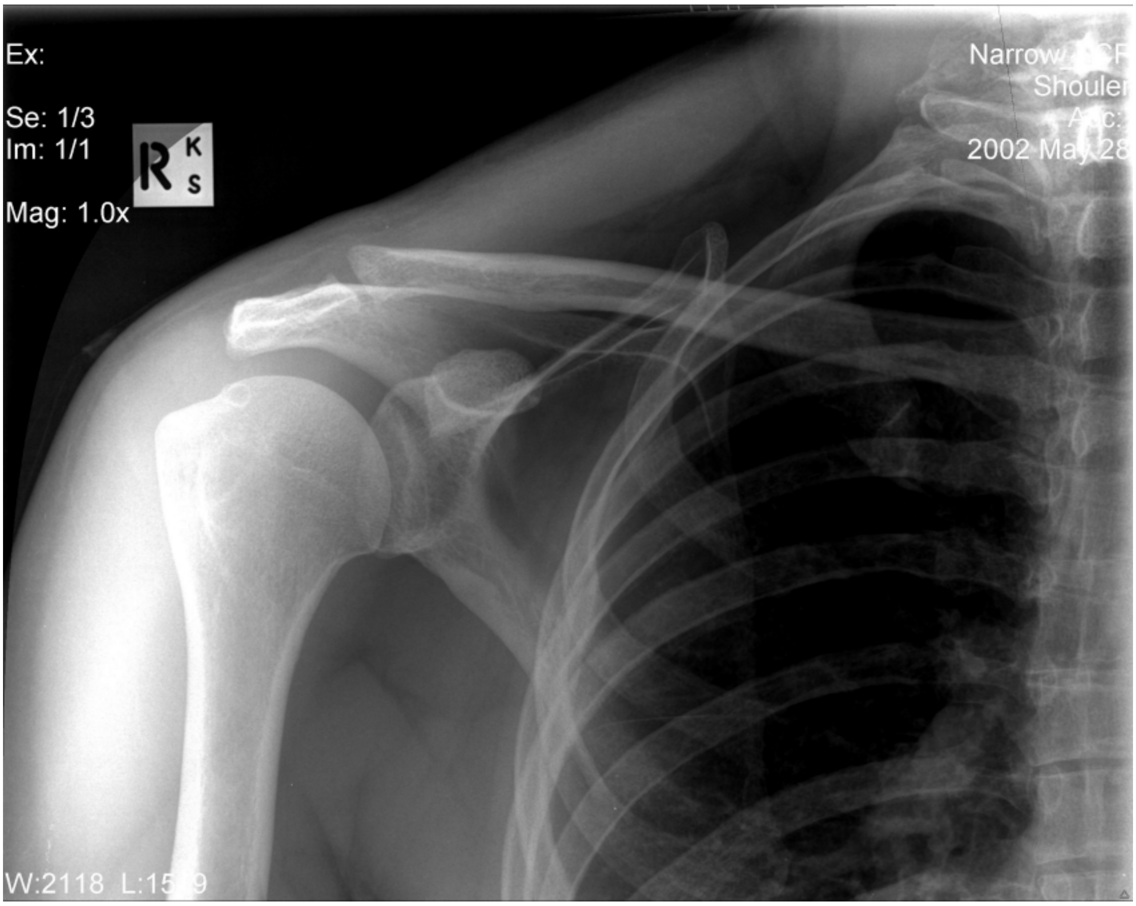


Figure 7.2 Boomerang RCM applied to Figure 7.1a with profile width = 1.0

Comparing Figure 7.1b and Figure 7.2, it can be seen that the periphery of the shoulder is much brighter in Figure 7.2. In Figure 7.2, alteration of the WW and WL was used to adjust the global brightness and contrast to optimise the glenoid region. With the use of these RCM factors, negative effects on the brightness of the chest and ribs areas in the image in addition to the peripheral regions of the shoulder have resulted. In this example, the selection of the profile width factor was too narrow for this anatomy.

7.3 Wedge RCMs

Wedge RCMs can be applied to a wider range of DR images than the boomerang RCM. In Figure 7.3b, a linear wedge RCM has been applied to an anterio-posterior projection of the thoracic spine DR image in Figure 7.3a. The radiographic contrast of Figure 7.3a was optimised for the lower cervical and upper thoracic spine region. In achieving this, the displayed optical density of the lower thoracic spine region has been negatively affected and appears white. This has occurred because of the large dynamic range of the image. At this contrast setting, the lower thoracic spine region of the image is beyond the dynamic range of the displayed contrast of the image. The user selectable factors of the wedge RCM are shown in Table 7.3.

Table 7.3 User selectable factors of wedge RCM – thoracic spine (Figure 7.3b)

User selectable factors (Figure 7.3b)
curved or linear: linear
end vector lengths (%) non-enhanced: 0 enhanced: 0
rotation: 180º
profile height: 2.5

The image in Figure 7.3b has high radiographic contrast evenly displayed over the entire thoracic spine. The use of an appropriate RCM has allowed visualisation of the entire spine in one image with high radiographic contrast. An alternative to achieve visualisation of the entire spine for Figure 7.3a would be to alter the radiographic contrast through the adjustment of the WW. If the entire spine were to be visualised in Figure 7.3a, a low radiographic contrast image would result. If high radiographic contrast is required in Figure 7.3a, manipulation of the WL would be required so that