Chapter 9

Subjective Evaluation – Survey Instrument

Chapters 6 and 7 described the development of radiographic contrast-enhancement masks (RCMs) for use in digital radiography (DR). Objective measurement of image quality was undertaken and discussed in Chapter 8. As radiographic images are subjectively evaluated in clinical practice for quality, a means of having clinical practitioners evaluate DR images modified by RCMs was devised. A survey was designed to gain opinions of professionals within the medical imaging and allied areas.

This chapter reviews the development of the survey instrument, details the requirements of providing clinical quality images in a format that can be viewed so that opinions can be obtained, and discusses image and digital RCM selection. Considerations of potential bias when undertaking surveys and ethical considerations when involving human participants in a research project are also discussed.

9.1 Establishing the Need and Method for a Survey

When comparing imaging techniques to determine the highest amount of detail (spatial resolution) in the image or to determine the highest optical density range (contrast resolution) in the image, quantitative methods are employed (Bushberg *et al*; 2002; Curry *et al*, 1990). However, image quality relies on human perception and is subjective by nature (Krupinski, 2003; Wang & Langer, 1997). When subjective assessment is needed, approaches other than quantitative methods may be undertaken. Surveying people's opinions is one such method.

Approaches to undertaking surveys are many and varied (Sapsford, 1999). A common survey technique is to design a written questionnaire on the research topic and then sample the population by eliciting responses from participants (Sapsford, 1999). Medical imaging research adds difficulty in that images often need to be visualised as part of gaining a response from participants.

When the research survey method requires participants to visualise pathology within the image, analysis of receiver operating characteristics (ROC), as first described by Metz (1978), is a very useful method. ROC are useful when comparing imaging techniques to determine the most appropriate method for detecting pathology (Metz, 1978, 1988). A recent search on the medical/health journal database, Medline®, with the search word "ROC", revealed many hundreds of articles using this technique. Although ROC is a popular method to determine diagnostic accuracy, it does not seek opinions as to the qualitative aspects of images. The focus of this research is not to determine diagnostic accuracy of the RCM methods. It was therefore determined that ROC would not be an appropriate method to evaluate the subjective qualities of an image.

An approach to evaluate the subjective qualities of the RCM methods was needed. Prior to the advent of DR, conventional film/screen (F/S) radiography was the accepted method of undertaking general radiographic examinations. With the advent of computed radiography (CR), CR was typically compared to the previous imaging standard, that of F/S radiography. Comparison of CR to F/S was often undertaken by comparison of ROC curves for each imaging modality (Colin *et al*, 1998; Kundel *et al*, 1997; Ludwig *et al*, 2000; Müller *et al*, 1996c; Prokop *et al*, 1993; Weatherburn *et al*, 2002; Wilson *et al*, 1991; Wu *et al*, 2000). As discussed above, ROC would not be an appropriate method of evaluating the subjective qualities of the RCM methods. Although similar, the approach taken by Wilson *et al* (1994) for comparisons of CR and F/S differs to that of usual ROC method. The approach taken by Wilson *et al* (1994) still evaluates diagnostic accuracy. Here radiologists were able to score, using a binary scale, the visibility of features in both CR and F/S images that lead to a diagnosis from the image.

Subjective comparison has been undertaken between varying DR processing methods. Comparison of varying image processing techniques was undertaken in projects by Müller *et al* (1996a) and Müller *et al* (1996b). For each of the image processing techniques observers rated the visibility and detectibly of pathologies within the image. No direct comparison of images was undertaken. A similar approach was undertaken by Welander *et al* (2002). In this project, to test image processing techniques, holes from 1 – 12mm were drilled in varying thicknesses of

aluminium. Observers were asked to count the holes visible in each image and report their findings.

Evaluation of varying image processing techniques has also been undertaken by comparative methods. In a study undertaken by Sailer *et al* (2004), the authors compared two digital image processing techniques. In this study, observers directly compared the two images resulting from different image processing techniques in a side by side fashion. In a study by Tingberg & Sjöström (2005), the x-ray tube voltage was varied to produce 10 images for chest and pelvis CR radiographic examinations. Observers evaluated the quality of each image individually against a predefined standard reference image. The standard reference images were based on usual tube voltages used in F/S radiographic examinations. A similar method of subjective evaluation was undertaken by Oda *et al* (1997). Again the modified image was compared side by side with a standard image. Varying thickness of Lucite plates were placed behind a radiographic chest phantom. Two different image processing techniques were used on the images. The two images without Lucite, using the same image processing techniques as the comparative image, were designated as the standard images.

RCMs are variable in shape to suit the anatomy within the image and in the degree of contrast adjustment. These parameters will be altered by the radiographer viewing the image and applying the RCM. It will be the radiographer's clinical judgement that sets the parameters to optimise the image for later viewing. In this project the parameters of the applied RCMs have been set by the researcher, an experienced radiographer. Alternative dynamic range control methods to RCMs have been previously discussed in Chapter 8 and an objective comparison of these methods and the RCM methods has been undertaken. Siegel *et al* (2006) indicate that dynamic range control methods such as digital latitude equalisation and contrast enhancement techniques, in mammography examinations, vary greatly depending on radiographic factors used. General radiographic examinations require a greater range of radiographic factors than mammography examinations. As such, dynamic range control methods would vary to a greater extent in general radiographic examinations than in mammography examinations. Given the large range of dynamic range control methods as indicated by Siegel *et al* (2006), RCM would need to be directly

compared to many such dynamic range control methods. The most appropriate method for comparison of the RCM methods in this project is therefore to select a standard image. The selection of a standard image for comparison in this project was the non-modified image or the original image before the application of the RCM.

To determine the effectiveness of digital RCMs against a standard image a survey technique that asked specific questions as to the qualitative aspects of the viewed images was needed. Lund *et al* (1997), in their comparison of conventional F/S radiography and CR skeletal extremity imaging, chose to ask qualitative questions of the participants. Three radiologists and three orthopaedic surgeons were asked questions of pathologies seen within 27 images. They were also asked to rank the images, both F/S and DR, on a 4 point scale on the qualitative aspects of contrast, sharpness and overall quality of the image. The scale used was 1 = excellent, 2 = good, 3 = fair and 4 = poor. It could not be determined from the paper whether or not the participants were given guidance as to what constituted high quality contrast, sharpness and overall quality. Results were reported using averages of the rating responses.

Swee *et al* (1997) also chose to survey qualitative aspects in their comparison of F/S and DR images of the hand and wrist. In that study 50 patients who were undergoing bilateral hand radiographic examinations had one hand imaged with F/S and the other imaged using DR. Six radiologists were asked, amongst other things, to comment on overall contrast, overall density and overall impression as to whether one image was different from the other. Each image of the patient's hands was given the title "A" or "B". The scale used by Swee *et al* (1997) was a scoring system between -3 and 3. For each qualitative assessment area, their basis of comparison was:-

-3 indicates A is significantly better than B

-2 indicates A is much better than B

-1 indicates A is slightly better than B

0 indicates A is similar to B

1 indicates B is slightly better than A

2 indicates B is much better than A

3 indicates B is significantly better than A

Results were reported using an average score and a standard error of the mean.

Brettle (2001) suggested that misinterpretation of medical images can occur following complex image post-processing of the image. A digital frame of reference (DFOR) should be included when viewing a modified image so that the viewer can see the effects of the modification. The DFOR is a test image that is displayed in its original context. The DFOR test image receives the same post-processing as the medical image. The modified DFOR is also displayed. A side-by-side comparison of the test images enables the viewer to see the effects of post-processing and understand the effects in the medical image.

These survey methods (Lund *et al*, 1997; Swee *et al*, 1997) are appropriate ways of surveying qualitative aspects of contrast, sharpness and overall quality in DR images. Side-by-side comparison of images is also supported by Brettle (2001). The RCM survey design was based upon the methods of Lund *et al* (1997) and Swee *et al* (1997). with aspects of Brettle's (2001) side-by-side comparison. In the RCM research, the most appropriate method of evaluating image quality was a direct comparison of images, rather than those discussed by Lund *et al* (1997) and Swee *et al* (1997). Images, with an appropriately applied RCM and an image without a RCM applied, were viewed side-by-side. This side-by-side approach allowed participants in the RCM survey to compare images and visualise their quality differences. From the participants' comparisons and responses to the survey questions, assessment of the RCM benefits and performance were made.

9.2 Potential Bias in Image Evaluation

Survey methods can be subject to bias (Foddy, 1993; Sapsford, 1999). Kelly *et al* (1997) and Brealey & Scally (2001) identified specific areas of bias in medical imaging studies. Although the focus of their articles was on diagnostic performance in detecting the presence or absence of pathologies, many of the potential areas of bias are relevant in image evaluation studies.

Both Kelly *et al* (1997) and Brealey & Scally (2001) discuss similar areas of bias. The main categories are those that affect external validity and internal validity of the study. One of the main determinants of external validity is sample size (Keller, 2001; Keppel, 1991). This is discussed in detail in the Section 9.3.

Patient selection or patient cohort inclusion may affect the external validity of the study (Brealey & Scally, 2001; Kelly *et al*, 1997). Patient selection or patient cohort could introduce a bias of images in the study where the patient's gender, age and/or physical size could be weighted. Therefore patient selection for image inclusion in the RCM survey was designed to ensure an equal weighting of images in regard to patients' age and physical size. It was felt that in the evaluation of image quality aspects, patients' gender was not a relevant factor.

The selection of an appropriate "gold standard" is another area of potential bias (Brealey & Scally, 2001; Kelly *et al*, 1997). The selection of gold standards is applicable in ROC studies (Metz, 1978). Although there is no gold standard per se in the RCM survey, the identity of the RCM modified image was known only to the researcher.

Potential aspects that can affect the internal validity of a study have been identified as observer biases (Brealey & Scally, 2001; Kelly *et al*, 1997). Observer biases can be subdivided into observer variability, intrinsic inter-observer variability, intra-observer variability and independence of interpretation bias.

In the RCM survey, observer variability could occur due to the inclusion of participants who were not familiar with medical imaging and the evaluation of

imaging quality. To reduce the effect of this potential bias, participant involvement was limited to radiographers, radiologists or other professionals who had direct links with medical imaging. From this selective inclusion it was expected that participants would have an appreciation of what constitutes image quality when viewing medical images.

Intrinsic inter-observer variability may occur if more that one participant is involved in the project's survey (Kelly *et al*, 1997). However, if the sample size were reduced to only one participant, this would have a greater effect on validity than the intrinsic inter-observer variability of a large sample size. There is a need to obtain external validity through the use of many participants viewing multiple images. Intrinsic inter-observer variability can be overcome by the correct use of statistical methods and analysis (Kelly *et al*, 1997). Statistical methods and analysis are detailed in Chapter 10.

Intra-observer variability is related to the subjectivity and reproducibility of results from a single observer (Kelly *et al*, 1997). Problems of subjectivity and reproducibility of results can be overcome by repeating the survey with the same participants at a later date. However, repetition of the survey would increase the logistic and resourcing issues. These are discussed in Section 9.4. Given these issues, it was not planned to repeat the RCM research survey with each participant. As such, the results could potentially be affected by participants' subjectivity and variability. However, with a statistically significant sample size of participants, intra-observer variability should be minimised (Brealey & Scally, 2001).

Another aspect that needed to be considered for the RCM survey is independence of interpretation. Such biases can result from participants not being independent from the results. Biases that could result can be overcome by "blinding" the participants (Brealey & Scally, 2001; Kelly *et al*, 1997). Participants were blinded to the identity of the RCM-enhanced image and the original unaltered image. These details were known to the researcher only.

9.3 Sample Size

Sample size and the method of image viewing by the participants needed to be considered for RCM survey. In the research of Lund *et al* (1997), six participants viewed 27 cases with a total sample size of n = 162, and in the Swee *et al* (1997) project, six participants viewed 50 cases, a sample size of n = 300.

Several authors (Beam, 1992; Obuchowski, 2000; Obuchowski & Zepp, 1996; Scally & Brealey, 2003) have examined sample size requirements in medical imaging research. These authors focused on sample size for ROC analyses. The issues discussed by these authors may not be directly relevant to determining qualitative aspects within images. Keppel (1991), Keller (2001) and Eng (2003) took a more generalised approach to determination of sample size. As detailed in Chapter 10, it was determined that a sample size in the order of 350 would have sufficient statistical power for statistical significance. Increasing statistical power decreases the likelihood of an error of not rejecting a false null hypothesis, a so called Type II error (Eng, 2003; Keller, 2001; Keppel 1991; Kinnear & Grey, 2000). Relaxing the significance level, a sample size in the order of 100 would still provide results with a significant power (Keppel, 1991). After reviewing the discussions of Lund *et al* (1997), Swee *et al* (1997), Keppel (1991) and Keller (2001), a sample size of 100 was determined to be the minimum. For the RCM survey, the minimum targeted sample size for the number of images compared was determined to be in the order of 350.

9.4 Participant Access to the Images

Access to and viewing of the images by the participants in the research of Lund *et al* (1997) and Swee *et al* (1997) occurred at the clinical site where the studies were undertaken.

It was previously discussed that the application of RCM to DR images would have benefits in eight or nine anatomical regions. Given a minimum sample size of 350 image comparisons, this would then require approximately 45 participants in the

RCM research survey. The resources and logistic implications of having 45 participants attend a rural site where the researcher was located in Australia to compare images had to be considered. It was expected that participant numbers would be reduced if they were required to travel long distances and sacrifice a day of their time. Funding for participants' travel costs was limited. Therefore, an alternative means of accessing and viewing the images was required.

9.5 Survey Tool Design

The purpose of the survey was to elicit responses as to whether the appropriate application of a RCM improved the quality within the image. The method chosen to ascertain quality differences between DR and F/S by Swee *et al* (1997) was to compare co-lateral images of patients' hands. Using a similar method for the RCM survey would entail the administration of ionising radiation to patients. As RCMs are applied as a post-processing application, the design of the survey tool could be done without prospective need for the administration of ionising radiation. Images that had been previously acquired for clinical purposes could be used. The comparison by the RCM survey participants would then be of a clinical image and the same clinical image with the application of an appropriate RCM.

As discussed in Chapter 5, clinical viewing of DR images allows the viewer to perform some post-processing functions. Typical post-processing functions are manipulation of the image's optical density (brightness) and displayed contrast, adjustment of image's displayed size through pan and zoom functions, and spatial enhancement functions such edge sharpening and smoothing. For images to be evaluated under clinical DR conditions, these functions would need to be available for the viewer to manipulate.

Also discussed in Chapter 5 were post-processing functions of dynamic range control. These post-processing functions have similar effects on the image to those of RCM methods. Chapter 8 discusses objective comparisons of RCM and eight dynamic range control methods. The dynamic range control methods selected for the objective comparisons were a sample of such methods from the Agfa-Gevaert

company, one of the manufacturers of clinical CR systems. Within the Agfa-Gevaert approach to dynamic range control, the radiographer adjusting the image has two values of MUSI and latitude reduction that can be altered on a scale from 0 to 6. There exists a vast range of adjustments from one manufacturer to alter the dynamic range within an image.

The design and size of the question within a subjective survey must be limited to promote respondents completion of the survey (Foddy, 1993; Sapsford, 1999). Comparison of RCM modified images and a vast range of other methods of dynamic range control would increase the size of the survey compared to comparison of a single image. Therefore, the survey was designed to compare the RCM method against the single most appropriate image, that being the original image

Images for the comparisons in this study needed to be sent to and viewed by the participants due to the resource and logistic implications discussed above. The images also needed to be in digital format to allow participants to manipulate post-processing functions so that the images could be evaluated under typical clinical conditions.

It was expected that the application of a RCM to an image would enhance the local displayed contrast within the anatomy in the image where the RCM was located. This would reduce the display effect of the high subject contrast differences that may be apparent in the original image, thus providing a better range of optical densities within the modified image. With a better overall range of optical densities within the image, it was expected that all the anatomy would be easier to visualise without the requirement for large contrast and optical density changes. These expected effects and benefits would then form the basis of the questions that needed responses from the participants.

The survey methods used by Lund *et al* (1997) and Swee *et al* (1997) did not elicit any information on the degree of quality difference between images. Any quality differences were determined only by virtue of the total of responses selecting one image over another. Responses from the RCM survey participants regarding the level of quality difference between images were deemed important information.

Kelly *et al* (1997) and Brealey & Scally (2001) discussed the need for the inclusion of a broad patient cohort. RCM performance under different patient conditions needed to be determined. The patient cohort needed to include patients with variables of different age, size and presence or absence of pathology. The most appropriate design to include images with these various factors was a factorial design (Cobb, 1998; Keppel, 1991). In a factorial design two or more independent variables are manipulated at the same time within the same experiment (Keppel, 1991). The three independent variables within the study images were patient age, patient size, and presence of pathology.

Within each of the independent variable factors, it was decided to subdivide each factor into two distinct levels. Age was divided into "young" and "old", size was divided into "small" and "large", and pathology was divided into "pathology present" or "normal". The three factors, being independent of each other, could then be included in each image. The use of three factors, each with two distinct levels, provided a possible mixture of eight factor combinations. These combinations are shown in Table 9.1. Each anatomical region to be viewed and assessed by RCM survey participants needed the eight combinations to be present so as to provide patient cohort inclusion validity for the RCM survey.

Table 9.1 Possible combinations of the 3 factors

Age	**Size**	**Pathology**
Young	Small	Pathology Visualised
		Normal
	Large	Pathology Visualised
		Normal
Old	Small	Pathology Visualised
		Normal
	Large	Pathology Visualised
		Normal

9.6 Ethical Issues

The proposed RCM research survey required the involvement of human participants and the use of clinical medical images. Ethical issues had to be considered.

Surveying humans for their opinions requires ethical considerations. Such considerations include:

1. seeking potential participants' permission for their involvement
2. explaining the level of their involvement in the survey
3. providing some background so they can make an informed decision as to whether they are willing to participate;
4. ensuring participants of anonymity in the reporting of the project and allowing them to opt out of the project at any time (National statement on ethical conduct in research involving humans, 1999; Sapsford, 1999).

A participant information sheet (Appendix 3) and consent form (Appendix 4) were devised ensuring that these ethical considerations were incorporated.

The collection of clinical human images also has ethical considerations. When images are used in a research project, any patient identification needs to be removed. The de-identification of DR images is discussed below.

An application was made to Curtin University of Technology's Human Research Ethics Committee for ethical consideration as to the use of participants in the RCM research survey and for the use of clinical images. Ethics approval from Curtin University of Technology's Human Research Ethics Committee was received in November 2002.

Participant consent forms were sent to all potential RCM research survey participants. This form was provided in both printed and electronic format. Participants were asked to complete and return the consent form. For the return of the consent forms, pre-addressed reply-paid envelopes were included in the RCM survey packages.

9.7 Collection and Collation of Images

Clinical DR images needed to be collected to provide an image database for the RCM survey. Anatomical regions where it was proposed that the RCM would have benefits in viewing DR images are listed in Table 9.2. A broad range of images from each anatomical region, to include examples of different patient age and size and to include examples of normal and pathological conditions, needed to be collected and collated.

Images were transferred on to an IBM compatible personal computer (PC) for storage and for the application of a digital RCM and without loss of image data. Reduced quality can result from loss of image data. Some DR units allow for image output format to be in full Digital Imaging and Communications in Medicine (DICOM) format, whereas other DR units have output formats in lossy compressed formats only, such a Joint Photographic Expert Group (JPEG). DICOM format maintains both spatial resolution and contrast resolution of the image (as fully discussed in Chapter 4). Image quality was maintained by use of the DICOM format.

Table 9.2 Anatomical regions where RCM could be beneficial in diagnostic radiographic examinations

Anatomical Region	Radiographic Projection(s)
abdomen	horizontal ray
cervical spine	lateral
facial bones	lateral
feet	AP and oblique
femur (proximal end)	AP and lateral
hands	PA, oblique and lateral
shoulder	AP
thoracic spine	AP
thoraco-lumbar spine	lateral

Computed radiography (CR) is the type of DR that is most commonly used in clinical practice. Discussion on the differences between CR and DR can be found in Chapter 4. Three manufacturers of CR units had equipment installed in clinical sites

within Australia. Of these three, one manufacturer had only one clinical site and this CR unit did not allow for DICOM output (S. Brown, 2002, personal communication). Another manufacturer had DICOM output in its latest model of CR equipment only. At the time of collection of images, no clinical site for this equipment was available within Australia (D. Doran, 2002, personal communication). The manufacturer Agfa Gevaert (Nunawading, Victoria) provided DICOM output on all its CR units (S. Osbourne, 2002, personal communication).

Three clinical sites that had Agfa Gevaert CR units were approached to seek access to their archived CR images for the RCM research project. Ethics approval for the collection of the CR images was also sought from and given by each of the clinical sites. Ethics approval for the use of de-identified images was sought from and given by Curtin University of Technology's Human Research Ethics Committee.

The three sites from which CR images were collected were:

1. Radiology Department, Westmead Hospital, Westmead, NSW (a major public teaching hospital)
2. Dr Perrett and Partners, Adelaide, SA (a private radiology clinic)
3. Medical Imaging Department, Flinders Medical Centre, Bedford Park, SA (a major public teaching hospital)

All images collected were previously deemed suitable for clinical diagnosis by the radiographers who were responsible for the radiographic examination.

The Agfa Gevaert CR units allowed for copying of the CR images to CD ROM. During the copying process, the option within the copying program to de-identify the images was selected. This option removed the patient's name and ID number from the image file's header. No other means of identifying the patient was collected.

Approximately 400 images in total were collected from the three clinical sites. This number provided a large range of images within each of the nine anatomical regions identified above. Images from each anatomical region were then subdivided into categories of various patient-related factors as listed in Table 9.1.

The categories of “young” and “old” were determined by the appearance of the bones within the image. The bone appearance in the “young” category was that of well calcified bone with good cortical bone thickness and good trabecular patterns visible within the image. Another indicator for inclusion in the “young” category was the presence of epiphysial plates within the image. Size categories were labelled as “small–medium” and “medium–large”. Soft tissue size visible within the image was the determinant of the category in which the image was placed. The researcher’s prior knowledge of viewing radiographic images was used to make the above category determinations. The determinant of whether an image was placed in the “pathology” or the “normal” category was whether any pathology was seen by the researcher. It must be noted that because the researcher is not medically qualified only pathology obvious to the researcher was included in the “pathology” category. Where there was any doubt as to the absence or presence of pathology, the image was excluded from the RCM survey database.

Following categorisation of the images, it was decided to reduce the anatomical regions from the nine listed in Table 9.2 to eight, by combining images of the hand and femur into a region called “other”. Subdivisions of the hand and femur regions revealed that not enough variation of patient-related factors of age, size and pathology had been collected to included eight combinations of the factors in each region. Other considerations within the RCM survey contributed to the decision to reduce the number of anatomical regions to eight. These considerations are detailed in Section 9.8. The two combined anatomical regions of the hand and femur included all eight combinations of patient-related factors. The reduction to eight anatomical regions, each region having eight images with a unique combination of patient-related factors, gave a final number of 64 images in the RCM survey.

Images were then coded by anatomical region and by patient-related factors, as listed in Table 9.3. The codes allowed for ease of identification of characteristics of anatomical region and patient-related factors in the image. For example, image E3 was an image of the abdomen with patient-related factors of “young” age, “med–large” size, and “normal” pathology. The patient-related codes were not made available to the RCM survey participants.

Table 9.3 Image codes for anatomical region and patient related factors

Anatomical Region		Patient-Related Factor Groups			
A	Shoulder - AP	1	Young	Small - Med	Normal
B	C Spine - Lat	2	Young	Small - Med	Pathology
C	T Spine - AP	3	Young	Med - Large	Normal
D	T/L Spine - Lat	4	Young	Med - Large	Pathology
E	Abdomen	5	Old	Small - Med	Normal
F	Facial Bones	6	Old	Small - Med	Pathology
G	Feet	7	Old	Med - Large	Normal
H	Other	8	Old	Med - Large	Pathology

9.8 Survey Image Design

The factorial design of the RCM survey tool allowed for images to have patient-related factors of age, size and pathology characteristics in each image. There were a total of eight patient-related factor groupings. The number of anatomical regions was reduced to eight. This allowed for ease of design of the number and combination of images to be viewed and compared by the RCM survey participants.

Eight anatomical regions and eight patient-related factor groups meant that participants viewed a total of eight image pairs. Each of the image pairs viewed was from a different anatomical region and had a different group of characteristics of patient-related factors. RCM survey participants thus viewed images from every anatomical region, which included every patient-related factor group listed in Table 9.3. Eight sets of image data were collated using this method. Each participant was given access to one of the eight sets of image data. Multiples of each of the image data sets were required and needed to be distributed to the participants.

It was anticipated that the viewing and comparing of a pair of images would take a maximum of 5 minutes per set. The maximum time anticipated for each participant to complete the tasks was thus 40 minutes. Participant cooperation is an area discussed by Sapsford (1999). The “amount of time” requirement to complete a survey is a factor that can contribute to non-completions. It was anticipated that non-completions of the survey would be reduced by limiting and providing an estimate of the time required to complete the tasks within the RCM survey.

9.9 RCM Application to Survey Images

Each of the 64 images selected for use in the survey required an application of an appropriate RCM. The researcher, an experienced clinical radiographer, drew on previous knowledge to best apply the RCM to each individual image in a manner that he expected would be used in the clinical environment. Each image was viewed using a PC based image viewing program and a RCM was selected. The original image was read into the program, Matlab® (MathWorks Inc., Natick, USA), which had been used for the development of the RCMs. Appropriate shape and enhancement characteristics of the RCMs were selected and entered into the algorithm. The RCM was then applied to the image. The RCM modified image was displayed and viewed using the Matlab® display function. Subjective assessment of the RCM's effects on the original image was made by the researcher. A trial and error process occurred in the assessment of the RCM's effect on the original image. If subjective assessment determined that the RCM effects were not optimised, modifications to the RCM characteristics of shape and enhancement were made. The modified RCM was then reapplied to the original image. Viewing and assessment processes were repeated as necessary. When the modified image was optimised following the subjective assessment, the modified image was saved as an image file separate from the original image. Matlab® algorithms used to save the original and RCM modified image are provided in Appendices 2d and 2e respectively.

The selection of the RCM and characteristics required a choice between a wedge RCM and a boomerang RCM. The user selectable characteristics of the wedge shaped RCM and the boomerang RCM are listed in Table 9.4. Full description of RCM development, characteristics and applications was provided in Chapters 6 and 7.

Table 9.4 Characteristics of wedge and boomerang RCM

Wedge RCM Characteristics	**Boomerang RCM Characteristics**
curved or linear; if curved, S-shaped or Gaussian	right or left shoulder
end vector lengths (to control the location of the wedge)	plan view curve (*q*)
degree of rotation	profile width (*s*)
profile height	profile height

The application and selection of the shape and enhancement characteristics of the digital RCM was a learning process. Initial applications of RCM on the original images required repeat applications to modify the shape and enhancement factors. Assessment and selection of appropriate RCM factors improved with experience. Later applications of RCM on the original images required fewer repeat applications.

Following modification of the original image and saving of the modified image file, further image coding occurred. The original and modified images in the image pair had characteristics of anatomical region and patient-related factors. The code identifying these characteristics was retained, and a new code number was added to the end. The new code identified which of the image pair was the original and which was the modified image. A code of “1” and “2” was used within the image pair. A code of “1” or “2” was not uniquely given to either of the original or modified images. The allocation of the codes was done so that half of the original images were coded with “1” and the other half were coded with “2”. When a code number was give to the original image in the image pair, the modified image was allocated the other number. This coding was undertaken so that there would be no means of identification of the original or modified image by the participants, from the image label details. The image codes and details of the RCM characteristics used on each modified image are shown in Tables 9.5a–h.

Tables 9.5 a–h Image codes and RCM characteristics of the modified image

(Filter types: a = boomerang filter; b – h = wedge filters.

Description of characteristics provided below last table of each filter type)

a

Original	**Modified**	R or L	Curve	Height	Width
Shoulder-A1-1	Shoulder-A1-2	R	2.5	2.5	2.5
Shoulder-A2-2	Shoulder-A2-1	L	2.3	2.3	3.5
Shoulder-A3-1	Shoulder-A3-2	R	2.7	2.5	3
Shoulder-A4-2	Shoulder-A4-1	R	2.5	3	2.5
Shoulder-A5-1	Shoulder-A5-2	L	2.5	2	2.8
Shoulder-A6-2	Shoulder-A6-1	R	2.6	3	2.8
Shoulder-A7-1	Shoulder-A7-2	L	2.8	3	2.5
Shoulder-A8-2	Shoulder-A8-1	L	2.6	2.2	2.5

where: R = right and L = left;
Curve = degree of curvature on plan view;
Height = enhancement factor of the "thickest" part of the boomerang *and*
Width = factor for the width of the boomerang

b

Original	**Modified**	C or L	Value	Rot Ang.	Non-Enh %	Enhanced %	Height
CSpine-B1-1	CSpine-B1-2	C-G	2	0	70	30	1.6
CSpine-B2-2	CSpine-B2-1	C-G	2	0	60	30	1.6
CSpine-B3-1	CSpine-B3-2	C-G	2	-50	70	30	1.6
CSpine-B4-2	CSpine-B4-1	C-G	2.5	35	70	30	1.6
CSpine-B5-1	CSpine-B5-2	C-G	2	30	70	30	1.6
CSpine-B6-2	CSpine-B6-1	C-G	2	20	60	30	1.65
CSpine-B7-1	CSpine-B7-2	C-G	2	10	70	30	1.6
CSpine-B8-2	CSpine-B8-1	C-G	2	20	60	30	1.6

c

Original	**Modified**	C or L	Value	Rot Ang.	Non-Enh %	Enhanced %	Height
TSpine-C1-1	TSpine-C1-2	L		180	0	100	2.2
TSpine-C2-2	TSpine-C2-1	L		180	0	100	2.5
TSpine-C3-1	TSpine-C3-2	L		180	0	100	2.3
TSpine-C4-2	TSpine-C4-1	L		180	0	100	2.5
TSpine-C5-1	TSpine-C5-2	L		180	0	100	2.5
TSpine-C6-2	TSpine-C6-1	L		180	0	100	2.3
TSpine-C7-1	TSpine-C7-2	L		180	0	100	2.6
TSpine-C8-2	TSpine-C8-1	L		180	0	100	2.3

d

Original	**Modified**	C or L	Value	Rot Ang.	Non-Enh %	Enhanced %	Height
TLSpine-D1-2	TLSpine-D1-1	C-G	2.8	0	50	50	1.7
TLSpine-D2-2	TLSpine-D2-1	L		180	0	100	3
TLSpine-D3-2	TLSpine-D3-1	C-S	1.0	180	60	20	2
TLSpine-D4-2	TLSpine-D4-1	C-G	2.5	180	75	25	2.5
TLSpine-D5-1	TLSpine-D5-2	C-S	1.0	180	60	30	2.5
TLSpine-D6-1	TLSpine-D6-2	C-S	0.8	180	60	40	2
TLSpine-D7-1	TLSpine-D7-2	C-S	1.0	180	60	20	2.2
TLSpine-D8-1	TLSpine-D8-2	L		0	0	100	1.6

e

Original	Modified	C or L	Value	Rot Ang.	Non-Enh %	Enhanced %	Height
Abdo-E1-1	Abdo-E1-2	L		180	0	100	2
Abdo-E2-1	Abdo-E2-2	L		180	0	100	2
Abdo-E3-1	Abdo-E3-2	L		180	0	100	2
Abdo-E4-1	Abdo-E4-2	L		90	0	100	2.7
Abdo-E5-2	Abdo-E5-1	L		180	0	100	2
Abdo-E6-2	Abdo-E6-1	L		180	0	100	2.3
Abdo-E7-2	Abdo-E7-1	L		90	0	100	2
Abdo-E8-2	Abdo-E8-1	L		180	0	100	2

f

Original	Modified	C or L	Value	Rot Ang.	Non-Enh %	Enhanced %	Height
Face-F1-2	Face-F1-1	C-G	2.5	-110	50	40	3
Face-F2-2	Face-F2-1	C-G	3	-90	50	50	2.8
Face-F3-2	Face-F3-1	C-G	2.5	90	40	55	2.5
Face-F4-2	Face-F4-1	C-G	3	-90	50	50	2
Face-F5-1	Face-F5-2	C-G	3	90	50	45	2.7
Face-F6-1	Face-F6-2	C-G	2.5	-110	50	50	2.3
Face-F7-1	Face-F7-2	C-G	2.5	90	50	50	2.5
Face-F8-1	Face-F8-2	C-G	2.5	-90	70	30	2.2

g

Original	Modified	C or L	Value	Rot Ang.	Non-Enh %	Enhanced %	Height
Foot-G1-1	Foot-G1-2	L		180	0	100	2.5
Foot-G2-1	Foot-G2-2	L		-150	0	100	2.8
Foot-G3-1	Foot-G3-2	L		180	0	100	3
Foot-G4-1	Foot-G4-2	L		-145	0	100	2.8
Foot-G5-2	Foot-G5-1	L		180	0	100	3
Foot-G6-2	Foot-G6-1	L		-145	0	100	2
Foot-G7-2	Foot-G7-1	L		180	0	100	3.2
Foot-G8-2	Foot-G8-1	L		180	0	90	3.5

h

Original	Modified	C or L	Value	Rot Ang.	Non-Enh %	Enhanced %	Height
Other-H1-2	Other-H1-1	C-G	2.5	-135	60	40	2.2
Other-H2-1	Other-H2-2	C-G	2.5	180	40	50	2.3
Other-H3-2	Other-H3-1	C-G	2.5	-135	50	50	2.5
Other-H4-1	Other-H4-2	C-G	2	-135	40	60	2.5
Other-H5-2	Other-H5-1	L		0	0	100	2.2
Other-H6-1	Other-H6-2	L		-45	0	100	2.5
Other-H7-2	Other-H7-1	L		180	0	100	2.2
Other-H8-1	Other-H8-2	L		180	0	100	2

where: C or L is C-G = Gaussian curved; G-S = S-shaped curve and L = linear;
Value = degree of curvature;
Rot Angle = orientation of the wedge with respect to the top of the image;
Non-Enh % = % of the top of the image that is not influenced by the wedge filter;
Enhanced % = % of image that is covered by the wedge filter;
Height = height of profile or the enhancement factor of the “thickest” part of the wedge

The image file's header contained details about the image such as the number of rows and columns of pixels within the image. Details of image file headers were explained in Chapter 4. DICOM image file headers also contain information about the patient such as name and ID number, the imaging modality such as DR, and many parameters about the imaging modality. Original patient details were removed from the header of each image file during the transfer process. The image identification codes listed in Tables 9.5 a–h were written to the header where the patient's name and ID would normally be stored.

The computer program Matlab®, which was used to develop the RCMs and to apply the RCMs to the images, was also used to write the image identification codes to the header. This was undertaken to ensure that the identification codes were integrated into the image file. These codes formed part of the algorithms used for saving the image files and are shown in Appendices 2d and 2e. Another advantage of this procedure was that DICOM image viewing programs read the patient details from the header and display this information when the image is displayed. Participants would have image identification details on the computer screen when viewing the images. This enabled participants to identify their choice of preferred image as either "image 1" or "image 2".

9.10 Image Viewing Tool

A means of distribution, storage and viewing of the images was needed so the participants could view and compare the original and modified images. Participants could not attend the rural research site due to resource and logistic limitations with the number of participants required in the survey. A practical alternative was to have the participants view and compare the images on their own PCs. Images would need to be forwarded to the participants at their place of employment or to their home. Sixteen images, eight image pairs, needed to be viewed and compared by each participant. Each image, in DICOM format, was 10 to 12 Mbytes in size. A convenient means of achieving this, for both the participants and researcher, was needed.

Web based distribution of the images was considered. Images could be placed on a web server and participants would then access the web site, download the images and complete the evaluations. Several issues were considered with this distribution option. The problem of download time for large file sizes via the web is well recognised and is highlighted as a disadvantage when using web based distribution by Zhang *et al* (2003). This problem becomes greater when web access is via home phone lines.

Compression of the images is a means of reducing download time. Image compression takes two general forms, lossy compression and lossless compression (Baxes, 1994). In lossy compression the image has irretrievable loss of information. Following decompression the image suffers some level of quality loss. Lossless compression results in no loss of information and the displayed image exhibits no quality loss following decompression.

Images on the web are commonly stored in JPEG format (Zhang *et al*, 2003). Conversion of images in DICOM format to JPEG format is a means of compression (Baxes, 1994). If this method were used, the bit-depth of the DICOM image would be reduced from 12 bit-depth with 4096 potential display values to 8 bit-depth with 256 potential display values. This is a form of lossy compression and could potentially cause a reduction of image quality in viewing of JPEG images.

Authors (Eraso *et al*, 2002; Slone *et al*, 2000) differ in their opinions as to the quality of decompressed images. Eraso *et al* (2002) concluded that diagnostic accuracy was reduced when high compression ratios were used with lossy compression. Slone *et al* (2000) concluded that there was no difference between observer performance when lossless compression was used. Lossless compression when downloading images in DICOM format would require decompression programs at the user end. Participants would have to ensure they had access to such a decompression program and that it was used correctly.

Testing the performance of the digital RCMs across a range of anatomy and patient-related factors was deemed important. The RCM survey design meant that an approximately equal distribution of images was needed with different anatomy and

patient-related factors. If a web based distribution system was to be used, a means of ensuring approximately equal comparison of the different image anatomical regions would be needed. This posed another problem for web based distribution of the images.

It was deemed that the best and simplest method of storage and distribution of the images to the RCM survey participants would be via a CD ROM. A group of eight image pairs could be placed on a CD ROM. The equal distribution of the eight anatomical regions that were needed for evaluation in the project was therefore under the control of the researcher. Distribution of the CD ROM would be via post to each of the participants.

Consideration was also needed as to how the RCM survey participants would view the images once they had received them. It could not be expected that each participant would have access to a DR unit and that the DR unit would allow the importation of external image files. A means of viewing the images needed to be incorporated onto the CD ROM. Having a DR image viewing program on the CD ROM would also add consistency to the way in which each participant viewed the images. There would be reduced observer variability if every participant used the same DR image viewing program.

An evaluation of five public domain PC based medical image viewing programs was undertaken. An important factor in the selection of these five programs was that each had to have an open, rather than a restricted, licence. Distribution of the selected program to the RCM research survey participants could then occur without any breach of licence conditions. The five medical imaging viewing programs were found by a search of the internet. Each program was then downloaded and installed onto the researcher's personal computer.

The five PC based medical image viewing programs were:

1. OSIRIS, version 4.18 (University Hospital of Geneva; http://www.expasy.ch/UIN)
2. DicomWorks, version 1.3.5 (Dicom Works; http://www.dicomworks.com)
3. ImageJ, version 1.30 (National Institute of Health, USA; http://rsb.info.nih.gov/ij)

4. SimpleDicom Viewer, version 2.0 (UPMC Health Systems; http://www.radiology.upmc.edu/software)
5. eFilm, version 1.4.1 (eFilm Medical Imaging System; http://www.eFilm.net)

The criteria for assessment of the medical image viewing programs, in order of importance, were:

1. ability to manipulate and ease of use of the displayed image contrast and optical densities (so-called window width and window level)
2. ease of selecting, opening and viewing an image or image pair
3. ability to view images side by side
4. ability to magnify areas within the image (pan and zoom)
5. ability to perform other post-processing functions such as edge enhancement and smoothing
6. ease of copying/burning the program onto a CD ROM.

Comparison and evaluation of the medical imaging viewing programs using the above criteria is shown in Table 9.6.

Since the evaluations were undertaken, Escott & Rubinstein (2003) have completed an in-depth review of free DICOM image viewers. Only the first four viewing programs listed above were reviewed. The program eFilm has since become a commercial product and the latest versions have strict licensing requirements that would prohibit distribution and multiple use. Although software versions are not mentioned by Escott & Rubinstein (2003), many similar issues with the first four software viewing programs listed above were found.

Tables 9.6 Comparison of medical imaging viewing programs

	1	2	3	4	5	6
	Displayed image contrast and optical densities	**Viewing an image or image pair**	**View images side by side**	**Magnify areas within the image**	**Post processing functions**	**Copying/burning the program**
OSIRIS Version 4.18	Included and easy to use. Limited range of window levels and widths.	Difficult to use. Need to know location and name of image file. Images open to full file size resolution and need to be reduced in size to fit within monitor resolution. Some DICOM file format difficulties.	Difficult to use. Separate image windows need to be opened.	Included. Would need to include detailed instructions.	Included. Would need to include detailed instructions.	Manual copying/ burning plus individual copying of the image pair.
DicomWorks Version 1.3.5	Included and easy to use.	Easy to use. Could preselect a list of "patient" images for inclusion. Image opens to fit within monitor resolution. Must select each image from "patient" list and open individually.	Difficult to use. Separate image windows need to be opened.	Included. Would need to include detailed instructions.	Included. Would need to include detailed instructions.	Manual copying/ burning plus individual copying of the image pair.

ImageJ Version 1.30	Included and easy to use.	Need to know location and name of image file. Images open to fit within monitor resolution.	Difficult to use. Separate image windows need to be opened.	Included. Would need to include detailed instructions.	Included. Would need to include detailed instructions.	Manual copying/ burning plus individual copying of the image pair.
SimpleDicom Viewer Version 2.0	Included and easy to use.	Need to know location and name of image file. Images open to fit within monitor resolution.	Difficult to use. Separate image windows need to be opened.	Not included.	Not included.	Manual copying/ burning plus individual copying of the image pair.
eFilm Version 1.4.1	Included and easy to use. Good visual controls that are easy to understand.	Easy to use. Can preselect a list of "patient" images for inclusion. Images open to fit within monitor resolution. If more than one image is opened, orientation is a side-by-side within the same window.	Easy to use. Separate image windows open when a "patient" file has more than one image.	Included. Would need to include detailed instructions.	Included. Would need to include detailed instructions.	Easy to use. The program builds a list of "patient" files and images selected and sends them to the CD ROM burner along with the viewing program.

The program selected for use as the viewing program in the RCM research survey was eFilm, version 1.4.1. This version is still public domain and has an unrestricted licence. The major difference between this and the other viewing programs evaluated was ability to view the two images in a side-by-side orientation within the same window. This was deemed a crucial difference, as survey participants would need to compare the original and modified images. Other viewing programs could display multiple images at the same time. The difference was that these viewing programs opened multiple display windows. The survey participants would be required to resize each image window so that the images could be viewed side-by-side. This could require resizing of the images to fit within the resolution of the computer monitor. The viewing program eFilm automatically resized and displayed both images within the one window. Figure 9.1 shows the full-screen side-by-side image layout used by eFilm.

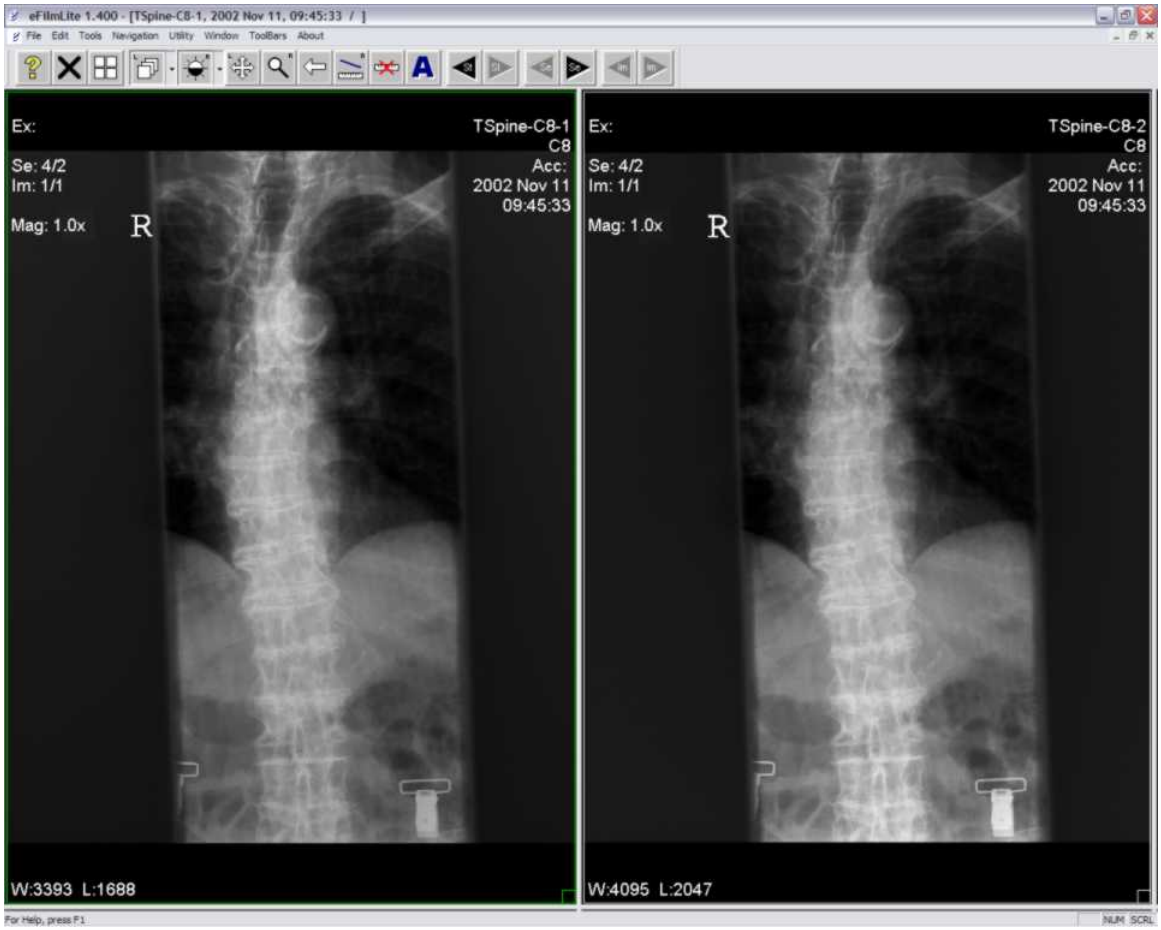

Figure 9.1 Image pair layout within eFilm for side-by-side comparison

eFilm, version 1.4.1, also has a built-in sub-program that assists with the burning of images to CD ROM. A single or multiple “patient” files could be selected for burning to the CD ROM. eFilm collated the images under separate “patient” names and copied them to a separate directory or folder within the computer. On completion of the “patient” selections, eFilm copied a version of its viewing program to that directory. On opening this version of eFilm, the “patient” details were listed and available for opening by the viewer.

Eight separate directories were created, one for each of the eight CD ROMs to be burned. The image placed in the directory had previously been given a “patient name”. This name was one of the codes listed in Tables 9.5a–h corresponding to first image in the pair. The selection of this “patient name” code was used as a means of identifying an image pair and then used to open the images for display. Figure 9.2 shows the list of image pairs, displayed as “patient name”, available for displaying from one of the CD ROMs using the program eFilm.

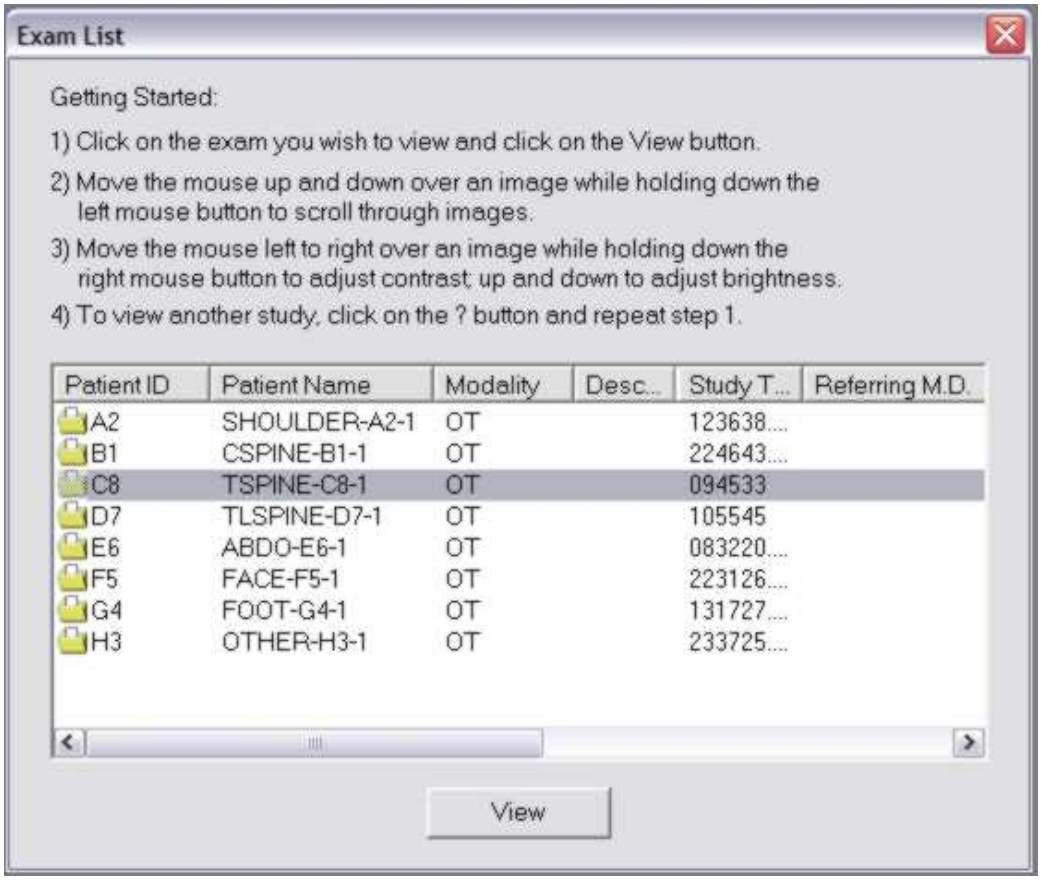

Figure 9.2 Dialogue window for opening images within the program eFilm

It was also decided that the CD ROMs should be auto-starting. The program eFilm should automatically load and open when the CD ROM was placed in the CD ROM drive. The dialogue window seen in Figure 9.2 was displayed after the eFilm had automatically started following the insertion of the CD ROM into the drive. An auto-start program was added to each of the eight directories so that this could occur. The contents of these directories could then be burned to CD ROMs. These eight CD ROMs were the master CD ROMs from which duplicates were made.

9.11 Use of PC Monitors for Displaying the Images

The proposed method of opening and viewing image pairs in the RCM research survey was to use the viewing program eFilm on the participants' PCs. It was recognised that problems exist when viewing medical images on PC monitors (Hemminger *et al*, 1995; Kondoh *et al*, 2001; Ricke *et al*, 2000). Variations in performance of colour cathode ray tubes (CRT) monitors exist between makes and models of CRT monitors (Kondoh *et al*, 2001). Hemminger *et al* (1995) highlighted a problem of linearising the perceived display output brightness on video display monitors. The levels set by the brightness and contrast functions within the display program can output brightness to be displayed differently on different monitors. Ricke *et al* (2001) reported that low quality monitors used in low cost PCs can affect perception of low-contrast detail in the images.

The types of monitors used to display the images also affect observer performance (Krupinski & Roehig, 2001; Krupinski *et al*, 2003). An important characteristic noted by Krupinski & Roehig (2001) was that observer performance was improved when using monochrome monitors compared to colour display monitors. These observations were generalised across a range of medical imaging examinations. More specific areas of observer performance were reported by Doyle *et al* (2002) and Cederberg *et al* (1999). Cederberg *et al* (1999) evaluated observers' performance in dental radiology using various monitors. Their conclusion was that observer performance was independent of the visual characteristics of the monitor used. In their review of reporting of DR images of the hands, Doyle *et al* (2002), concluded

that there was no observer performance difference between results using different computer monitors.

Several authors (Wang *et al*, 2002; Wang & Peng, 2002) have suggested that monitors used for the display of medical images need to be objectively measured to determine the display characteristics of the monitors. The Society of Motion Picture and Television (SMPTE) pattern should be used as a test image. Following display of the SMPTE pattern, contrast-detail characteristics of the display monitor can then be optimised. Others authors (Ikeda *et al*, 2002; Ishihara *et al*, 2002; Spekowius, 1999) suggest that the monitor's luminance is the important objective measure for observer performance when using monitors. Both Ikeda *et al* (2002) and Ishihara *et al* (2002) state that low luminance from monitors adversely affects observer performance. Spekowius (1999) discussed the importance of adjustment of the monitor's luminance and resolution prior to displaying medical images. It was further suggested that this is even more important when colour display monitors are used.

For the RCM research survey, it was felt that providing and asking participants to optimise their PC monitor using the SMPTE pattern could be beyond the capabilities of some of the participants. Requiring participants to undertake such a task could result in increased non-completions of the survey.

A simple set of instructions for optimisation of colour monitors' characteristics of resolution and luminance was devised and provided in the participant information sheet (see Appendix 3). If the RCM research survey participants followed these instructions, their monitors would be optimised to their best performance. RCM research survey participants were asked to view and compare images using the display program eFilm. The two images in the image pair were displayed at the same time. Any problems of observer performance due to the monitor's performance would be equalised between both images.

9.12 Request for Participant Involvement

It has been previously discussed that the minimum sample size for external validity of the RCM research survey was considered to be the evaluation of 350 image pairs. A minimum of 45 participants was therefore needed in the RCM research survey. A method to request participation in the survey that would reach and exceed the minimum number of participants was needed.

The Australian Institute of Radiography (AIR) has established a list-server, AIRNEWS, for the use by its members (AIRNEWS - The AIR List-server, 2004). A list-server is an internet based means of corresponding with other people in a group. AIR members are able to pose questions and respond to those questions through AIRNEWS. It was deemed that AIRNEWS would be an appropriate means of requesting involvement of potential participants in the RCM research survey, as its members work in the profession of medical imaging. Obtaining participants who were radiographers would increase the intrinsic validity of the survey, as discussed in Section 9.2. Initial posting of a request for participants via AIRNEWS was made in August 2003. Several repeat postings were made.

Colleagues and acquaintances of the researcher in the medical imaging area were approached both to be participants and to seek other participants from their places of employment. Email was the most commonly used means of communication to these people.

Names and addresses of people who expressed an interest in being involved in the RCM survey were collated. These people were later sent a package including a CD ROM and the survey questionnaire.

9.13 Questionnaire Design

A questionnaire was needed, to elicit responses from the RCM survey participants in two general areas. These general areas were demographics and responses on image comparison.

Kelly *et al* (1997) and Brealey & Scally (2001) discussed the importance of reducing observer variability. It was planned that RCM research survey participants would be from professions within the medical imaging area or allied fields. A question asking the participant's profession was included to ensure that only participant responses from these professional areas were used in the analysis. The analysis of the survey results could then also be subdivided by professional group.

Krupinski (2001) suggested that there are experience-related differences in reading medical images when viewing images on a monitor. It was decided to include in the questionnaire a question about the participant's years of experience. Analysis of the survey results could then also be undertaken to determine if there were any experience-related differences between participants with differing years of experience. Black (1999) and Polgar & Thomas (1998) suggest that some types of data are best ranked in ordinal groups. The participants' years of experience were categorised into four groups, as listed in Table 9.7.

Tables 9.7 Categories of participants' experience

Less than 5 years experience
Between 5 and 10 years experience
Between 10 and 15 years experience
More than 15 years experience

Other demographic data that might have been collected, such as participant's gender, was not considered relevant in the analysis of the survey results.

The more important section of the RCM research survey was the comparison of the modified and original images. It was expected that the application of a RCM to an image would have benefits that improved image quality. Questions relating to the quality difference in the expected areas of RCM benefits needed to be devised and included in the questionnaire. These expected areas of RCM benefits were:

1. Enhancement of local displayed contrast within the anatomy in the image where the RCM was located
2. Provision of a better range of optical densities within the image

3. Provision of easier manipulation of displayed image contrast and optical density.

Foddy (1993) indicated that two types of questions could be asked in a survey, open and closed questions. The advantages of closed questions over open questions (Foddy, 1993) are that closed questions allow respondents to answer the same question so that answers can be meaningfully compared; produce less variable answers; are easier to answer; and produce answers that are easier to computerise and analyse.

Open questions would not have been as appropriate as closed questions in the RCM survey. Questions also needed to be clear and unambiguous and have a standardised presentation (Sapsford, 1999). These characteristics were incorporated into the questions in the RCM research survey.

A pilot study was undertaken to obtain feedback on the questions to be used in the RCM research survey. Questions relating to the expected area of RCM benefits were devised. A CD ROM containing the viewing program eFilm, eight pairs of images and pilot questionnaire was sent to 10 people. The participants in the pilot survey all had been or were working within the field of education and had knowledge of the medical imaging area. Feedback was requested on the questionnaire and the participant information sheet's wording, structure and design. Feedback and comments were returned following this request. Questions and the participant information sheet were modified to reflect comments received.

The refined questions for the RCM research survey participants were:

1. Which image shows the better range of optical densities?
2. In which image is all anatomy easier to visualise?
3. Which image allows for simpler contrast and density manipulation for optimal visualisation of all anatomy?
4. Which of the images has the higher image quality?

Sub-questions to the first three questions were devised to determine the participant's level of preference on quality improvements between images. An indication from the

RCM survey respondents as to the degree of improvement of one image over the other above was deemed a useful indicator of the level of preference of their chosen image. These questions were:

1. Please indicate the level of increase in improvement in range of optical densities.
2. Please indicate the level of increase in improvement in ease of visualisation.
3. Please indicate the level of increase in improvement in ease of optimisation.

A Likert scale is typically a 5 or 7 point scale with opposing response options and a middle or neutral option (Black, 1999). A Likert scale was therefore not suitable for these questions to ascertain level of improvement. Instead, an ordinal scale of 1 to 5 was used to measure the level of improvement. The scale steps were between 1, representing a "very small" improvement in the participant's preferred image, and 5, representing a "very large" improvement in their preferred image. Details of the scale steps are shown in Table 9.8.

Table 9.8 Scale for improvement levels in the participant's preferred image

Scale Response Amount when comparing images				
1	2	3	4	5
very small	small	moderate	large	very large

Eight sets of all the questions were required for the questionnaire. Each of the questions listed above was asked for each anatomical region evaluated. Identification of the particular image pair being evaluated within an anatomical region was needed. The RCM survey participants were asked to identify the image pair's code for each region they evaluated. This facilitated later correlation of participants' responses to the patient-related factors within the image.

Images were sent to the RCM survey participants on CD ROM. Potential participants were approached mainly through the AIR list-server and personal email. As these are digital means of communication, it was decided that the option of a digital response to the survey would be provided to the participants.

Microsoft Excel® is a spreadsheet computer program designed as an easy tool for calculating and charting data (Person, 1993). Microsoft Excel® has many advanced features, such as radio buttons which enable easy selection of options. Complex functions such as macros and parsing data from one page into another can be undertaken. Microsoft Excel® was an ideal tool for the creation of a digital survey response form due to these features. A Microsoft Excel® response form for the RCM survey was developed. The form included radio buttons with the number of options corresponding to the possible closed responses available to the participant. Macros were used to parse the value selected using the radio buttons to a second Microsoft Excel® page within the spreadsheet. Extraction of the data to a collated file could then easily be undertaken. Macros were also used so that participants could navigate easily through the form. The form was created without any preselection of the radio buttons so as not to potentially bias the participants' responses to that question. The first section of the Microsoft Excel® response form, showing radio button options and navigation aids, is shown in Figure 9.3. (Note that this survey was undertaken when the researcher was a student at Curtin University of Technology. The survey form still indicates this association.)

Participant Questionnaire Form

Research Project:
Tissue Compensation Algorithms in Digital Radiography
A Doctoral Research Project being undertaken
through Curtin University of Technology

Principal Investigator:
Robert Davidson
Ph 02 69332503 (work)
Email: *rdavidson@csu.edu.au*

Department of Medical Imaging
Curtin University of Technology
PO Box U1987
Perth WA 6845

Please check appropriate responses

Occupation

☐ Radiographer ☐ Radiologist ☐ Other

Years of Experience

☐ < 5 Years ☐ 5 to 10 Years ☐ 10 to 15 Years ☐ > 15 Years

RESPONSES

Select buttons below to jump to the appropriate response set or scroll down

Go to Shoulder | Go to C Spine | Go to T Spine | Go to T/L Spine | Go to Abdomen | Go to Facial Bones | Go to Feet | Go to Other Ext.

Response Information Please enter the image ID in the box: eg. for shoulder: A1 ID's are found on the 2nd row of the image details

Image Number Response

Use the number in the "patient name" area. This is located in the top right hand corner of the image on the top row and is either "1" or "2"
NB. The no. 1 image is not necessarily the left hand image

Scale Response Amount
when comparing images

1	2	3	4	5
very small	small	moderate	large	very large

Image Set Responses: Shoulder Shoulder ID : ☐

A Which image shows the better range of optical densities? ☐ 1 ☐ 2

Please indicate the level of increase in improvement in range of optical densities. (using above scale) ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Figure 9.3 First section of digital participant response form developed in Microsoft® Excel

It was anticipated that not all survey participants would have access to Microsoft Excel®. A similar version of the survey form was developed in Microsoft Word®. This form is attached as Appendix 5. The Microsoft® Excel or Microsoft Word® response forms were included in digital format on each CD ROM. Instructions were provided as to how to access the forms and how to use them. Using the Microsoft Word® response form, the radio button options were not available to the participants. Participants were requested to type an "X" next to their desired response. Participants using either Microsoft Excel® or the digital version of the Microsoft Word® response forms were able to return the response form via electronic means. Either of the digital forms could be saved onto a 3½″ floppy disk provided and returned in the pre-addressed reply-paid envelope. Alternatively, the digital form could be emailed to the researcher.

It was anticipated that not all participants would have access to the Microsoft® range of products or email. The Microsoft® Word version of the form was printed and included in the RCM research survey package sent to the participants.

The package mailed to the RCM survey participants included:

- CD ROM with eFilm viewing and display program; eight pairs of images, one in each pair being the original image and the other the RCM modified image; electronic versions of the Microsoft® Excel or Microsoft® Word response forms and electronic versions of the instruction and consent forms;
- printed version of the Microsoft® Word response forms;
- printed versions of the instruction and consent forms;
- 3½″ floppy disk;
- pre-addressed reply-paid envelope.

Two hundred and seven potential participants' names and addresses were received. These were collated and printed onto mailing labels. Approximately 250 CD ROMs were copied from the eight master CD ROMs. Packages were mailed to potential participants over the period September to December 2003. The results of the survey are discussed in Chapter 10.