Development and validation of a psychometric scale for assessing PA chest image quality: a pilot study

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Aims and objectives

The aim of this study was to create a psychometric scale to assess image quality perception of postero-anterior (PA) chest X-ray images.
Methods and materials

This research study was conducted in two phases: Phase 1 - a literature review and focus group discussion to develop the image quality perception scale; Phase 2 - validate the scale using a series of 7 phantom images of known image qualities.

Literature review and scale development

A literature review was conducted in order to identify the determinants of image quality perception of a PA chest radiograph (1-4). Factors were developed into scale items suitable for creating the psychometric scale; this was guided by Bandura's theory of self-efficacy and the literature surrounding the construction of a psychometric scale [5, 6]. Since all images were acquired using a phantom, factors related to positioning and movement were excluded from the scale. The scale items generated and from the literature review were presented to a focus group consisting of radiographers and students. Amendments were made to the scale based on the focus group feedback. Some of the scale items were negatively worded in order to avoid affirmation bias. A 5-point Likert scale was used to quantify the response of the participants. Items that had negatively worded statements were reversed so that all responses were unidirectional for scoring purposes (i.e. a score of 5 indicated a higher level of self-efficacy).

Chest phantom images

Images were acquired on a Wolverson Acoma X-ray unit (high frequency generator with VARIAN 130 HS standard X-ray tube with a total filtration of 3 mm Aluminum equivalent). An adult anthropomorphic chest phantom (LungMan) [7] was positioned in accordance with Clark's Positioning in Radiography [8] for a PA chest projection with a source-to-image receptor distance (SID) of 180cm to mimic clinical conditions. The position of the phantom was kept constant in order to eliminate positioning errors. The primary x-ray beam was collimated to the edges of the image receptor (IR).

Images were acquired on the same 35cm x 43 cm Agfa Computed Radiography (CR) image receptor and image processing was undertaken using an Agfa 35-X digitizer. A secondary radiation grid was not used and all equipment quality control met the required specifications of Institute of Physics and Engineering in Medicine (IPEM)f report 91[9]. To simulate clinical conditions all images were displayed using a chest look up table. The pre-set contrast and brightness settings were used to display the images. Exposure factors, dose area product (DAP) and exposure index (EI) were recorded for each image.

Determination of exposure factor combination
A preliminary investigation was conducted to determine the exposure factor combinations required to produce 7 images to validate the psychometric scale. During the investigation, the kVp was initially fixed at 85kVp which reflected clinical practice. Images were then acquired at varying mAs values. The first image was acquired with an mAs of 1.6. Subsequent images were acquired by increasing the mAs by one increment allowed by the system. Based on group consensus it was concluded that there was no visual change in image quality perception when mAs was increased by one increment. Therefore, the mAs was increased in increments of 2, then 3, and finally 4 - when a noticeable change in visual image quality was observed. At 25 mAs the images were over exposed and the study was terminated because the anatomical detail visualized on the image was inadequate. A similar technique was then used to determine the range and increments of kVp. Consequently, 35 possible exposure combinations were identified.

**Image selection**

SNR was calculated for the 35 images using four regions [10]. Seven images were selected, representing low to high SNR. SNR ranking agreed with group consensus ranking. Three of the seven images (poor, mid- and high-quality) are demonstrated in Figure 1-3.

**Validation of the scale**

53 observers from 5 countries (student radiographers, qualified radiographers & radiology registrars) participated in scale validation. Observers were required to indicate their level of agreement with each scale item, where 1 was equivalent to strongly disagree and 5 was strongly agree. The draft scale consisted of 22 items. Each participant viewed the images on a 22 inch liyama ProLite liquid crystal display (LCD) monitors (B2206WS) with a resolution of 3 megapixels. Monitors were calibrated to DICOM grayscale standard display function (GSDF) the ambient lighting conditions were kept constant and dimmed. Observers were trained to be able to complete the scale validation task. For each image the scores from each participant were aggregated to reflect the overall quality of each image. It is necessary to say that each observer completed one scale for each of the 7 images. In total this means that 371 (53X7) scales were completed.

**Statistical Analysis**

All data were transferred to MS Excel 2010 (Microsoft Corp, Redmond, WA) where the mean values and the standard deviation were calculated. Using Excel mean SNR was plotted against the mean scale scores. A separate plot was also created for each of the 22 items. Following this, all data were transferred to SPSS Statistics for Windows, Version 20.0 (Armonk, NY: IBM Corp) where the Cronbach Alpha coefficients were calculated.
Images for this section:

Fig. 1: Low quality image (1)

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Fig. 2: Middle quality image (26).

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Fig. 3: High quality image (28)

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Results

Fifty three observers (final year undergraduate radiography students (n=28), postgraduates radiography students (n=2), radiography tutors (n=6), qualified radiographers (n=4) and 13 radiology registrars) completed the scale. Scores from each observer were aggregated to reflect the overall quality of each of the assessed images. The mean scale score was compared for each of the seven images against the SNR, DAP and EI.

The mean of scale score was lower for images with a lower SNR, 42.1 (SD=10.8) when compared with an image with a high SNR, 86.7 (SD=10.8). The mean scale score also showed a strong positive correlation with SNR (Figure 2, \( R=0.98 \); \( P<0.01 \)) (Figure 4).

The next step was to consider the responses of each of the 22-items across a range of image qualities. To facilitate this analysis three images were chosen with the lowest (17.18), mid (27.59) and highest (36.54) SNR. This would indicate that scale principally works across a wide range of qualities and therefore suggest acceptable scale validity. Mean values for each of the 22-items were plotted for each of the three images (Figure 5).

Next, internal reliability of the scale was assessed using Cronbach’s alpha to measure how well the items correlated with each other and how each item correlated with the total score[11]. Cronbach (1951) suggested a value of 0.6 as a standard lenient cut off point for each extracted factor [12]. However other authors have recommended 0.7 as the acceptable value for internal reliability [13]. The Cronbach values for all 7 images fall above these values (Table 4), indicating good internal reliability. Image-4 indicated the highest internal reliability for this study, with a Cronbach value of 0.896.

<table>
<thead>
<tr>
<th>Image set No.</th>
<th>Alpha Coefficients</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>0.792</td>
</tr>
<tr>
<td>2</td>
<td>0.833</td>
</tr>
<tr>
<td>3</td>
<td>0.874</td>
</tr>
<tr>
<td>4</td>
<td>0.896</td>
</tr>
<tr>
<td>5</td>
<td>0.837</td>
</tr>
<tr>
<td>6</td>
<td>0.854</td>
</tr>
</tbody>
</table>

Table 4. Demonstrates internal reliability coefficients for scale items across all image set.
**Fig. 4:** Changes in SNR trends against mean scale scores for the seven images (aggregated).

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Fig. 5: Responses for individual scale items for three images of differing qualities (Numbers at the ends of the lines correspond to the SNR).

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Conclusion

The aim of this project was to use self-efficacy to develop and validate an image quality perception scale for PA chest radiography. For our 22 item scale, we found a strong relationship between SNR and the scale score. This suggests that the perceptual measure of image quality is relatively valid and reliable. In all cases, Cronbach alpha coefficients were greater than 0.7 for all images. This suggests the scale has good reliability. The scale items are therefore consistent in measuring perception of image quality.

The development and validation of this image quality perception scale will allow the assessment of image quality perception in both clinical and academic environments. Although only a pilot, this study has taken the initial steps to create and validate a reliable scale for the assessment of PA chest radiographs. The scale, even in its current stage of development, could provide a valuable contribution to help standardize visual assessment of PA chest image quality. More work is needed to complete the development and validation process but this 22-item scale is a considerable improvement to the currently available scales.
Personal information

This project was conducted in collaboration with students and academics from Universities in Salford (UK), Oslo (Norway), Lausanne (Switzerland) and Groningen (The Netherlands) as part of an EURASMUS Summer School.

Further information on this project can be obtained from:-

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References