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

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ABSTRACT

Purpose: To develop and validate a psychometric scale for assessing image quality perception for chest X-ray images.

Methods: Bandura's theory was used to guide scale development. A review of the literature was undertaken to identify items/factors which could be used to evaluate image quality using a perceptual approach. A draft scale was then created (22 items) and presented to a focus group (student and qualified radiographers). Within the focus group the draft scale was discussed and modified. A series of seven postero-anterior chest images were generated using a phantom with a range of image qualities. Image quality perception was confirmed for the seven images using signal-to-noise ratio (SNR 17.2–36.5). Participants (student and qualified radiographers and radiology trainees) were then invited to independently score each of the seven images using the draft image quality perception scale. Cronbach alpha was used to test interval reliability.

Results: Fifty three participants used the scale to grade image quality perception on each of the seven images. Aggregated mean scale score increased with increasing SNR from 42.1 to 87.7 ($r = 0.98$, $P < 0.001$). For each of the 22 individual scale items there was clear differentiation of low, mid and high quality images. A Cronbach alpha coefficient of >0.7 was obtained across each of the seven images.

Conclusion: This study represents the first development of a chest image quality perception scale based on Bandura's theory. There was excellent correlation between the image quality perception scores derived using the scale and the SNR. Further research will involve a more detailed item and factor analysis.

Introduction

Chest radiography is one of the most frequently performed diagnostic radiographic examinations in the United Kingdom. A recent Health Protection Agency report (2010) showed that chest radiography represented 19.6% of all radiographic examinations.[1] Despite its dominance in the clinical assessment of a whole myriad of diseases the interpretation of a chest X-ray image is notoriously difficult.[2] Interpretation can be improved by evaluating images of optimum diagnostic quality. For this to be possible there needs to be robust mechanisms for assessing image quality.

Primary perception of image quality can be measured by asking observers to assess contrast, spatial resolution and noise of an image. Physical assessment can be undertaken by measuring the detective quantum efficiency (DQE), modular transfer function (MTF) and signal-to-noise ratio (SNR).[3] These parameters are, however, more of a measure of the system performance rather than the 'real' clinical image quality perception.

Before any realistic assessment of image quality perception can be made, the requirements need to be defined. These requirements

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include whether the necessary clinical information is contained within the image and whether this can be interpreted by the observer, rather than whether the appearance of the image is pleasing to the eye.[4] For measuring the actual clinical quality of an image (i.e. assessing images from real human or human simulated phantom) an observer performance measurement is needed. These perceptual measurements can be undertaken by assessing an image using the receiver operating characteristic (ROC),[5] and visual grading analysis (VGA). The latter could be through use of a grading scale of criteria. Such VGA systems have been used for studies investigating X-ray image quality perception of the pelvis and lumbar spine.[6–8]

A literature review highlighted that many articles relating to chest X-ray image quality perception investigated physical measurements (such as SNR) and dose reduction, rather than observer perception of image quality.[9,10] Articles which investigated perception of observer image quality have often been based on the Commission of European Communities (CEC) image criteria[11] or a modified version of those criteria. However, there are problems when using the CEC criteria, for instance they are outdated and researchers tend to adjust them according to their needs because the criteria were developed for images acquired on film-screen systems. Presently there is no published and validated perceptual scale for assessing image quality. Lack of such a scale can lead to a lack of consistency in evaluating image quality by perceptual means. There is, therefore, a need to create and validate scales for use by clinical and research staff.

Image quality perception assessment involves observers considering how much image detail (i.e. anatomical structures or abnormality visualisation) they can perceive. The approach often involves observers rating criteria using a Likert scale. This approach considers two issues: physical information within an image (stimulus or signal) and perceptual effect (psychological) that is related to human analysis of the perceived image.[12,13] For the latter, the approach we have taken to scale creation and validation capitalizes on Bandura's theory for self-efficacy. This theory provides a robust theoretical framework to guide the methodology of creating and validating a perceptual scale. This theory has been widely used in psychology and health fields. It gives a self-reported measure of an individual's perception of how confident they feel in relation to performing a specific task[14,15]; equally it can give a self-reported measure of somebody's attitude toward a given topic. On this basis the theory can be adapted to developing and validating a scale for determining perception of image quality.

With specific reference to exposure factors the aim of this study was to create a psychometric scale to assess image quality perception of postero-anterior (PA) chest X-ray images.

Materials and methods

This study was conducted within a 3 week residential summer school. Limitations of time meant data collection could only occur over a one week period. The research consisted of two phases: Phase 1 – a literature review and focus group discussion to develop the image quality perception scale; Phase 2 – validation the scale using a series of 7 phantom images of known image quality.

Literature review and scale development

A literature review was conducted in order to identify the determinants of image quality perception of a PA chest X-ray image.[11,16–18] 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.[19,20] Since all images were acquired using a phantom, factors related to positioning and movement were excluded from the scale. The scale items generated from the literature review were presented to a focus group consisting of radiographers ($n = 3$) and student radiographers ($n = 5$). The radiographers' post-qualification experience ranged between two and five years, whereas students participated in the focus group were all in their final year of study (i.e. third or fourth year). 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. 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 Acroma 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)[21] was positioned in accordance with Clark's Positioning in Radiography[22] for a PA chest projection with a source-to-image receptor distance (SID) of 180 cm 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 35 cm × 43 cm Agfa Computed Radiography (CR) IR 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) report 91.[23] To simulate clinical conditions all images were

Table 1
Demonstrates all the possible exposure factor combinations tested.

Image number	kVp	mAs
1	40	1.6
2	60	1.6
3	80	1.6
4	100	1.6
5	120	1.6
6	40	2.5
7	60	2.5
8	80	2.5
9	100	2.5
10	120	2.5
11	40	4
12	60	4
13	80	4
14	100	4
15	120	4
16	40	6.3
17	60	6.3
18	80	6.3
19	100	6.3
20	120	6.3
21	40	10
22	60	10
23	80	10
24	100	10
25	120	10
26	40	16
27	60	16
28	80	16
29	100	16
30	120	16
31	40	25
32	60	25
33	80	25
34	100	25
35	120	25