Chest Radiography - Lower Radiation Dose with Similar Image Quality

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**Aims and objectives**

Chest radiography (CXR) is one of the most utilized imaging investigations involving radiation across many medical specialties. The individual radiation dose of a CXR to the patient is relatively low, however, due to its frequent use, the contribution of the accumulated dose is substantial. Consequently, optimization of dose and image quality remains a challenging area of research.

Different exposure class and sensitivity of an Agfa computed radiography system could be used to optimize chest radiography resulting in a lower radiation dose using higher sensitivity parameter, but clinical verification was not well established.

Therefore, the aim of this study is to evaluate the radiation dose of CXR with a sensitivity value of 400 as in factory setting and to perform quality assessment of diagnostic applicability of dose-reduced CXR with a higher sensitivity value (sensitivity 600).

**Methods and materials**

Review of the CXRs performed for 100 consecutive adult patients in a regional hospital were conducted. There were 45 male and 55 female patients. Age ranged from 19 to 93, with a mean of 57.5. Paediatric patients (<18 years of age) were excluded. All CXRs were obtained with justified clinical indication. The images were obtained using sensitivity of either 400 or 600 by an Agfa 85X CR System. Fifty CXRs were obtained per acquisition technique and the assignment of patient to different technique was random. The two groups were matched with respect to patient body size during image inclusion.

Radiation dose of the CXR was quantified by the DRL, which was estimated with dose area product (DAP) derived from exposure measurements.

Two independent radiologists interpreted and rated all CXRs in different random order. All the images were masked for any patient clinical information and acquisition parameters. The image quality of CXR was assessed by ten criteria referenced by the European Guidelines On Quality Criteria for Diagnostic Radiographic Images (Table 1).

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Details</th>
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</table>

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Page 2 of 9
1. CXR performed at full inspiration (6 anterior ribs or 10 posterior ribs above diaphragm)

2. Symmetrical reproduction of thorax (spinous process located between the medial ends of clavicles)

3. Medial border of scapulae outside of lung fields

4. Reproduction of whole rib cage above diaphragm

5. Visually sharp reproduction of vascular pattern in lungs, especially for peripheral vessels

6. Visually sharp reproduction of trachea and proximal bronchi

7. Visually sharp reproduction of borders of heart and aorta

8. Visually sharp reproduction of diaphragm and lateral costophrenic angles

9. Visualization of retrocardiac lung and mediastinum

10. Visualization of spine through heart shadow

Table 1. Criteria for the assessment of CXR image quality as referenced by the European Guidelines On Quality Criteria for Diagnostic Radiographic Images.

(Key: Visualization = features are detectable but details are not fully reproduced; Reproduction = details are visible but not necessarily clearly defined; Visually sharp reproduction = details are clearly defined)

Differences of image quality ratings between the two acquisition techniques were assessed by the analysis of variance (ANOVA) with repeated measures. The agreement ratio for different criteria was calculated. Inter-observer agreement for the overall mean score of image quality was quantified using weighted Cohen Kappa statistics.
Results

There was a substantial reduction in radiation dose value of 32.8% by using image technique with sensitivity 600 (mean DAP= 10.00 cGycm^2) as compared to the CXRs taken with sensitivity 400 (mean DAP= 14.87 cGycm^2).

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>400</th>
<th>600</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>kVp</td>
<td>125</td>
<td>125</td>
</tr>
<tr>
<td>Exposure (mAs) mean</td>
<td>2.36</td>
<td>1.58</td>
</tr>
<tr>
<td>Exposure (mAs) range</td>
<td>1.72-3.76</td>
<td>1.27-2.20</td>
</tr>
<tr>
<td>DAP mean (cGycm^2)</td>
<td>14.87</td>
<td>10.00</td>
</tr>
<tr>
<td>DAP range (cGycm^2)</td>
<td>10.10-26.90</td>
<td>7.20-15.00</td>
</tr>
</tbody>
</table>

Table 2. Exposure and dose measurements for CXRs taken with sensitivity 400 and 600.

For the image quality study, the two raters demonstrated a high level of inter-observer agreement ratio in most of the criteria (ranging from 82.7% to 100%). The Kappa score for the overall mean score of image quality between the two radiologists was 0.547, representing moderate and clinically acceptable inter-observer agreement.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Details</th>
<th>Inter-observer agreement ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CXR performed at full inspiration (6 anterior ribs or 10 posterior ribs above diaphragm)</td>
<td>96.9</td>
</tr>
<tr>
<td>2</td>
<td>Symmetrical reproduction of thorax (spinous process located between the medial ends of clavicles)</td>
<td>82.7</td>
</tr>
<tr>
<td>3</td>
<td>Medial border of scapulae outside of lung fields</td>
<td>83.7</td>
</tr>
</tbody>
</table>
4  Reproduction of whole rib cage above diaphragm 98.0
5  Visually sharp reproduction of vascular pattern in lungs, especially for peripheral vessels 100.0
6  Visually sharp reproduction of trachea and proximal bronchi 90.8
7  Visually sharp reproduction of borders of heart and aorta 98.0
8  Visually sharp reproduction of diaphragm and lateral costophrenic angles 99.0
9  Visualization of retrocardiac lung and mediastinum 100.0
10 Visualization of spine through heart shadow 100.0

Table 3. Agreement ratio between the two raters for each image quality criterion as referenced by the European Guidelines On Quality Criteria for Diagnostic Radiographic Images.

<table>
<thead>
<tr>
<th>CXR</th>
<th>Mean image quality rating of radiologist A</th>
<th>Mean image quality rating of radiologist B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity 400</td>
<td>9.02</td>
<td>9.14</td>
</tr>
<tr>
<td>Sensitivity 600</td>
<td>9.12</td>
<td>9.16</td>
</tr>
</tbody>
</table>

Table 4. Mean image quality ratings of CXRs with sensitivity 400 and 600.

Analysis showed that there was no statistically significant difference in the overall mean image quality between the two groups of CXRs taken with different sensitivity and radiation dose (p=0.415). Both groups of CXRs showed satisfactory diagnostic applicability.
**Fig. 1:** This is a chest radiograph of a Chinese adult patient fulfilling several criteria referenced by the European Guidelines On Quality Criteria for Diagnostic Radiographic Images: visually sharp reproduction of vascular pattern in lungs, especially for peripheral vessels (blue arrow); visually sharp reproduction of trachea and proximal bronchi (yellow arrow); visually sharp reproduction of diaphragm and lateral costophrenic angles (red arrow); and visualization of spine through heart shadow (green arrow).
Fig. 2: This is a chest radiograph of a Chinese adult patient fulfilling the criteria of reproduction of whole rib cage above diaphragm (grey arrow) and visually sharp reproduction of borders of heart and aorta (purple arrow) as referenced by the European Guidelines On Quality Criteria for Diagnostic Radiographic Images.
**Fig. 3:** This is a chest radiograph of a Chinese adult patient that fails to fulfill some criteria referenced by the European Guidelines On Quality Criteria for Diagnostic Radiographic Images: there is no visually sharp reproduction of the right heart border (purple arrow), and the spine cannot be visualised through the heart shadow (orange arrow).
Conclusion

This study demonstrated that CXRs taken with sensitivity 600 effectively reduced the radiation dose to patient while maintaining sufficient image quality as compared with sensitivity 400, and should be applied to future standard CXRs acquisition. Similar clinical audit and quality assurance study could be extended to radiographs of other body regions to ensure adherence to the principles of radiation protection.

Personal information

References