Support Line and Tube Visibility in Chest Examinations Using Computed Radiography

Walter Huda, Clifford J. Belden, Laura A. Webb, and Carole K. Palmer

The visibility of support lines and tubes was compared in computed radiography (CR) and screen-film adult chest radiographs. Parameters investigated were radiation dose, image minification, and the use of unsharp mask enhancement. Five radiologists rated the visibility of support lines and tubes on a five-point scale ranging from 1 (entire course of line visible) to 5 (line not visible or only small portion seen). These CR results were compared with the visibility of support lines and tubes as assessed by the same readers for conventional screen-film radiographs (600 speed). Support line and tube visibility improved with image enhancement, image minification, and increasing radiation dose. At the same radiation exposure, support line and tube visibility of the screen-film combination was superior to that of standard CR images. Application of an unsharp mask enhancement algorithm to CR images, however, significantly improved support line and tube visibility in comparison to that obtained with the screen-film combination. It was concluded that unsharp mask processing is a valuable tool for improving the visibility of support lines and tubes in CR chest radiographs.

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KEY WORDS: Chest radiology; computed radiography; image enhancement; patient doses; support lines and tubes; computers; radiology

ONE MAJOR advantage of computed radiography (CR) systems is their wide linear response over four orders of magnitude, which permits films to be obtained with the required film density independent of the radiation level used to expose the CR imaging plate.1,2 With CR, the amount of radiation used to perform radiographic examination affects the level of radiographic mottle in the resultant image.4,5 CR systems allow images to be processed to enhance the visibility of selected image features and may employ differing sizes (minification) of the displayed image.6,7 Image quality, and the resultant imaging performance of CR, has been shown to depend on radiation dose,8 unsharp mask processing,9,10 and image display size.7,11 Increased knowledge pertaining to these factors for specific clinical applications would help to optimize the use of CR.12

Bedside chest radiography is an important clinical area of radiology with a continuing need to improve image quality.13 CR is an imaging modality which offers significant benefits when used to perform bedside examinations.2,3,12 An important role of bedside chest radiography in the intensive care unit setting is verifying the position of support lines and tubes and monitoring any changes in their location.14,15 In this study, CR chest examinations obtained from an adult medical intensive care unit (MICU) were used to assess the visibility of support lines and tubes in chest examinations as a function of radiation dose, image minification, and use of unsharp mask enhancement. In addition, the performance of CR was compared with that of a 600 speed screen-film combination normally used on this MICU.

MATERIALS AND METHODS

A Du Pont (El Du Pont de Nemours & Co, Wilmington, DE) Linx CR 400 unit, based on the Fuji AC-1, was used to generate film radiographs. Generation ST IIIN imaging plates were employed (35 cm × 43 cm), and radiographs were printed with either one or two images in the output film. When a two-image output was selected, the left-side image was processed to have the appearance of a conventional screen-film radiograph (standard), whereas the right-side image was processed with an unsharp mask algorithm (enhanced). The CR produces a hard-copy output on a 28 cm × 35 cm film resulting in an image minification of either two thirds or one half, depending on whether one or two images were printed on the film, respectively. Table 1 lists the processing parameters used by the CR system to process chest images used in this study where the unsharp mask enhancement parameters used were the default values provided by the manufacturer. The CR system used in this study, image processing algorithms, and explanation of the role of the image processing parameters listed in Table 1 are described in detail elsewhere.5,16,17

The CR system determines sensitivity (S) and latitude (L) parameters with an exposure data recognizer (EDR) system.8,17 The value of S selected by the EDR system ensures that the average exposure level is mapped to the correct film density. A uniform exposure of 1 mR (2.58 × 10⁻⁴ C/kg) on the imaging plate results in the EDR system generating an S value of approximately 200. For a given type of clinical examination obtained under similar conditions and processed in a consistent manner, the approximate relationship between S and radiation

From the Department of Radiology, University of Florida College of Medicine, Gainesville, FL.

Address reprint requests to Walter Huda, PhD, University of Florida College of Medicine, Department of Radiology, Box 100374, Gainesville, FL 32610-0374.

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0897-1889/97/1003-0006 $3.00/0

Table 1. Image Processing Parameters Used by The CR System

<table>
<thead>
<tr>
<th>CR Format</th>
<th>GA</th>
<th>GT</th>
<th>GC</th>
<th>GS</th>
<th>RN</th>
<th>RT</th>
<th>RE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2/3 (Standard)</td>
<td>1.1</td>
<td>E</td>
<td>1.6</td>
<td>-0.10</td>
<td>4</td>
<td>R</td>
<td>0.5</td>
</tr>
<tr>
<td>1/2 (Standard)</td>
<td>1.1</td>
<td>E</td>
<td>1.6</td>
<td>-0.10</td>
<td>4</td>
<td>R</td>
<td>0.5</td>
</tr>
<tr>
<td>1/2 (Enhanced)</td>
<td>0.9</td>
<td>A</td>
<td>1.5</td>
<td>-0.20</td>
<td>4</td>
<td>R</td>
<td>5.0</td>
</tr>
</tbody>
</table>

exposure (X) given by

\[ S = \frac{200}{X(\text{mR})} \]  

The L parameter is the exposure latitude where values of 1 and 2 correspond to dynamic ranges of 10:1 and 100:1, respectively. With the Linx CR system, the value of L is selected by the CR system based on an analysis of the image data and for chest examinations is between 1.6 and 2.6. To minimize the influence of the L parameter on the resultant film densities, only CR films with a value of L equal to 1.6 were included in the study evaluating line visibility.

Bedside chest examinations were performed with GE AMX IV (General Electric Corp, Milwaukee, WI) portable radiograph units, no antiscatter grids and a Focus-Film Distance (FFD) of 100 cm. The CR system accounted for only 25% of the chest radiograph examinations performed on this MICU and was compared with a 600 speed screen-film combination (Kodak Lanex Fast screen and Kodak T-Mar L [TML] film combination) normally used in this MICU. Average techniques for CR imaging plates (kVp and mAs) were, therefore, identical to those employed with the screen-film system. Most bedside chest radiographs on this MICU are taken at 75 kVp and between 1 and 2 mAs.

From these CR images, 9 two-thirds size films with a single standard image and 12 one-half size films, each containing a standard and enhanced image, were selected for assessment of line visibility. For comparison purposes, seven conventional screen-film radiographs were also evaluated. Films with poor positioning that hindered support line and tube visibility were excluded.

Five board-certified radiologists who routinely read bedside chest radiographs ranked the visibility of support lines and tubes using the five-point scheme summarized in Table 2. The radiologists were allowed to preview all cases to gauge the variability in image quality before the formal evaluation. Conventional and CR films were randomly presented on a light box in a darkened room in a single reading. A rank was allocated to each line by the radiologist and recorded by the investigator. Support lines and tubes present on an image that were not explicitly mentioned by the radiologist were assumed to have been missed and allocated a rank of five. A statistical t-test analysis for each type of line was performed by comparing the ranks assigned to screen-film radiographs with each CR image category. Categories 1 and 2 listed in Table 2 may be classified as being desirable for clinical diagnosis. An analysis was made of the percentage of images within each category and imaging mode that fell into this desirable classification.

RESULTS

Figure 1 shows the S and L histogram distributions for the first 137 CR studies performed in the MICU. The average value of the S parameter was 680, corresponding to a screen-film exposure of about 0.3 mR. Variations in the S parameter reflect different radiation exposures, and it is this feature that permits the influence of dose differences to be empirically investigated. About 50% of the CR examinations generated an L value of 1.6, which is the minimum value this CR unit employs to process chest examinations.

The total number of feeding tubes, endotracheal tubes, and vascular catheters in the radiographs employed in this study are summarized in Table 3. Also given is the percentage for each type of line missed by readers and assigned a rank score of five (ie, not visible). Feeding tubes were twice as likely