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Bedside Chest Radiographs in the Intensive care Setting: Wireless Direct Radiography Compared to Computed Radiography

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Objectives: To compare image quality, visibility of anatomic landmarks, tubes and lines, and other clinically significant findings on portable (bedside) chest radiographs acquired with wireless direct radiography (DRw) and computed radiography (CR).
Methods: In a prospective IRB-approved and HIPAA-compliant study, portable DRw (DRX-1C mobile retrofit portable wireless direct radiography, CareStream Inc., Rochester, NY) and portable CR (AGFA CR (DXG) version; NIM2103, AGFA Healthcare, Ridgefield Park, NJ) images of the chest were acquired within 24-hours in 80 patients in the intensive care unit (ICU). Image pairs of 75 patients (37% female) with a mean age of 60.7±16 years were independently compared side-by-side by 7 experienced thoracic radiologists using a five-point scale. When tubes and lines were present, the radiologist also compared an edge-enhanced copy of the DRw image to the CR image.
Results: Most radiologists found significantly fewer artifacts on DRw images compared to CR images and all readers agreed that when present, these artifacts did not significantly preclude the ability to evaluate anatomic landmarks, tubes and lines, or clinically significant findings. None of the radiologists (0/7) reported superior visibility of anatomic structures on CR images compared to DRw images and some radiologists (3/7) found DRw images significantly better for visibility of anatomic landmarks such as the carina (p=0.01–0.001). Most radiologists (6/7) found DRw images to be better or clearly better than CR images for position of tubes and lines, and edge-enhanced DRw images to be especially helpful for evaluation of central venous catheters and esophageal tubes (p=0.027-0.001). None of the radiologists deemed CR images superior for visibility of clinically significant findings.
Conclusions: Critical care chest radiography with a portable DRw system can provide similar or superior information compared to a CR system regarding clinically significant findings and position of tubes and lines.

Introduction

Chest radiography is the most frequently performed examination in diagnostic radiology.[1,2] Applications of portable (bedside) chest radiography span from screening healthy patients to evaluating critical abnormalities and position of tubes and lines in the most critically ill patients in the intensive care unit (ICU) setting. In the ICU setting, it is especially important to efficiently acquire high-quality portable chest radiographs to allow rapid and accurate interpretation by radiologists.

Portable chest radiography in the ICU setting can be acquired with digital radiography (DR) or computed radiography (CR) systems. Although DR systems are more expensive compared to CR,[1-5] they are easy to operate and have high spatial resolution, image quality, lesion-signal response, and a wide dynamic display range.[3,6] DR systems also allow for lower radiation[7-9] and better electronic postprocessing compared to CR systems. A scheduled Medicare multiyear payment reduction scheme will further incentivize the transition from CR to DR. Starting in 2018, the technical component of radiographs acquired with CR will be reduced by 7% until 2022. By 2023, the reduction will amount to 10%.[10]

Prior studies in the ICU setting have shown that wired or "tethered" DR systems help improve image quality while enabling efficient workflow and decreasing turnaround time.[11-16] Recently, portable DR systems with wireless capabilities (DRw) have become available. These systems allow rapid and often instantaneous wireless transfer of imaging data to viewing workstations for image quality assessment, while obviating the need for transporting and processing cassettes, which are essential steps in CR systems.[1,17]

The purpose of our study was to compare image quality, visibility of anatomic landmarks, tubes and lines, and other clinically significant findings on portable chest radiographs acquired with DRw and CR.

Materials and Methods

An institutional review board (IRB) for human subject research approved this prospective study and the requirement for informed consent was waived. This study was compliant with the Health Insurance Portability and Accountability Act (HIPAA).

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Image acquisition

This prospectively designed study included ICU patients for whom portable chest radiographs were acquired with an FDA-approved DRw system (DRX-1C mobile retrofit portable wireless direct radiography, CareStream Inc., Rochester, NY) and a CR system (AGFA CR (DXG) version; NIM2103, AGFA Healthcare, Ridgefield Park, NJ) within a 24-hour time frame. Images were acquired in 2011 over a 3-week period in an ICU of a tertiary academic medical center. The same radiologic technologist acquired each DRw and CR image pair to ensure comparable image quality. However, as the indication to image was based on clinical care, not all patients were imaged by the same technologist. The CR image was acquired before the DR image 50% of the time, and in reverse order for the second half of the study. Patients were positioned upright if possible; otherwise, the supine position was used. Regardless, patient positioning and source to image receptor distance were consistent for each image pair. Automatic exposure control was used in all instances. Grid systems were used only for larger patients, and if so were used for both the DRw and CR images. When tubes and lines were present, an edge-enhanced copy of the DRw image was created. The nonedge enhanced copy of the DRw will be referred to as native DRw image throughout the manuscript.

Image pair selection

Two fellowship-trained thoracic radiologists reviewed all images on a clinical workstation to identify 80 suitable image pairs by consensus. These radiologists did not participate in the actual image grading. Image pairs were excluded if there was more than a 24-hour delay between the acquisition of DRw and CR images, or if there was a substantial change in radiographic findings, including position of tubes and lines. For example, image pairs were excluded if there was interval insertion or removal of an endotracheal tube, esophageal tube, pulmonary artery catheter, central venous catheter, or peripherally inserted central catheter (PICC). Another exclusion criterion was interval development, resolution, or change in focal or generalized abnormalities between the 2 radiographs. Image pairs were downloaded from the clinical server in Digital Imaging and Communications in Medicine (DICOM) format and anonymized. A study co-investigator who did not take part in image interpretation or data analysis numerically coded the image pairs. None of the interpreting radiologists or co-authors were aware of the randomization key for image display.

Training of readers

Five of the 80 identified image pairs were randomly selected and used to train the radiologists charged with image grading. Seven board certified thoracic radiologists with 4, 12, 15, 18, 20, 25, and 38 years of experience in the interpretation of chest radiographs participated in a joint training session. The radiologists evaluated 5 image pairs to learn the evaluation criteria and grading system. These 5 image pairs were excluded from statistical analysis. Image pairs of the 75 remaining patients were then submitted for evaluation.

Image evaluation

All images were loaded onto an offline diagnostic DICOM compliant image interpretation workstation with dual monitors and evaluated in 2011. Both viewing monitors (3 megapixels each) were the exact same model and version (Barco Coronis Dual Head 3MP [MDCG-3120] Grayscale Display System) and were calibrated identically before image evaluation, including minimum and maximum luminance. The workstation was equipped with image viewing tools to perform interactive window and level adjustments, to zoom and pan, and to reverse gray scale, in order to mimic the tool set that is available on clinical workstations in our hospital. Reduced ambient lighting was ensured to mimic the environment of our chest radiograph reading room. Each of the 7 readers evaluated the 75 image pairs independently and in the absence of other radiologists. A research fellow trained in the use of the study software was available for assistance during all reading sessions.

Native DRw and CR image pairs were randomly displayed on the 2 monitors side by side (right or left side). No patient identifiers, image attributes, or labels were visible. The radiologists were completely unaware of the indication or diagnoses before the evaluation.

When tubes and lines were present ($n = 65/75$), radiologists were asked to compare the edge-enhanced copy of the DRw image to the CR image to specifically assess visualization of tubes and lines. The edge-enhanced copy was displayed only for image pairs that contained tubes and lines.

Evaluation criteria

Each radiologist graded the native DRw and CR image pairs for image quality, visibility of anatomic landmarks, tubes and lines, and other clinically significant findings. The specific criteria for image quality comprised separate assessments of noise, perceived sharpness, brightness and contrast, overall image quality, and image artifacts. Visibility of anatomic landmarks included assessments of the carina, right paratracheal stripe, right minor fissure, 3 consecutive intervertebral disk spaces in the retrocardiac region, and pulmonary vasculature within the inner two-thirds of the lungs. The position of tubes and lines including endotracheal tubes, esophageal tubes, PICC, central venous catheters, and

TABLE 1
Evaluation categories and specific study criteria used in our study

Evaluation category	Specific criteria
Image quality	Noise Perceived sharpness Brightness and contrast Overall image quality Image artifacts (if any)
Visibility of anatomic landmarks	Carina Right paratracheal stripe Right minor fissure Three consecutive disk spaces in retrocardiac region Pulmonary vasculature within inner 2/3 of lungs
Tubes and lines	Peripherally inserted central catheter Endotracheal tube Central venous catheter Pulmonary artery catheter Esophageal tube
Clinically significant findings	Visibility of pleural line of pneumothorax Extent of pleural effusion Ability to assess pulmonary opacification (consolidation/atelectasis) Conspicuity of septal lines Calcification of aortic arch Tracheal displacement relative to midline Acute fracture