SESSION I: Digital Imaging and Image Processing

Finding-Specific Display Presets for Computed Radiography Soft-Copy Reading

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Much work has been done to optimize the display of cross-sectional modality imaging examinations for soft-copy reading (ie, window/level tissue presets, and format presentations such as tile and stack modes, four-on-one, nine-on-one, etc). Less attention has been paid to the display of digital forms of the conventional projection x-ray. The purpose of this study is to assess the utility of providing presets for computed radiography (CR) soft-copy display, based not on the window/level settings, but on processing applied to the image optimized for visualization of specific findings, pathologies, etc (ie, pneumothorax, tumor, tube location). It is felt that digital display of CR images based on finding-specific processing presets has the potential to: speed reading of digital projection x-ray examinations on soft copy; improve diagnostic efficacy; standardize display across examination type, clinical scenario, important key findings, and significant negatives; facilitate image comparison; and improve confidence in and acceptance of soft-copy reading. Clinical chest images are acquired using an Agfa-Gevaert (Mortsel, Belgium) ADC 70 CR scanner and Fuji (Stamford, CT) 9000 and AC2 CR scanners. Those demonstrating pertinent findings are transferred over the clinical picture archiving and communications system (PACS) network to a research image processing station (Agfa PS5000), where the optimal image-processing settings per finding, pathologic category, etc, are developed in conjunction with a thoracic radiologist, by manipulating the multiscale image contrast amplification (Agfa MUSICA) algorithm parameters. Soft-copy display of images processed with finding-specific settings are compared with the standard default image presentation for 50 cases of each category. Comparison is scored using a 5-point scale with the positive scale denoting the standard presentation is preferred over the finding-specific processing, the negative scale denoting the finding-specific processing is preferred over the standard presentation, and zero denoting no difference. Processing settings have been developed for several findings including pneumothorax and lung nodules, and clinical cases are currently being collected in preparation for formal clinical trials. Preliminary results indicate a preference for the optimized-processing presentation of images over the standard default, particularly by inexperienced radiology residents and referring clinicians.

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SOME DIAGNOSTIC IMAGING experts envision approximately 50% of all radiology services worldwide will be filmless in 5 years and as

many as 70% filmless in 10 years out.¹ Picture archiving and communication systems (PACS) encompass the technologies required for digitally acquiring, distributing, displaying, and archiving radiologic images, and provide the basis for these optimistic predictions for transforming the practice of radiology. This is particularly true for the utilization of PACS technologies for the cross-sectional imaging modalities (ie, computed tomography [CT], magnetic resonance imaging [MRI], and ultrasound), but less well developed for the conventional projection x-ray, which makes up approximately 70% of all the radiologic examinations performed today.

Much work has been done to optimize the display of cross-sectional modality imaging examinations for soft-copy reading. For example, window and level tissue presets are typically provided for CT examinations, and format presentations such as tile and stack or cine modes are generally configurable for viewing multiple sequences in MRI studies. Less attention has been paid to the display of digital forms of the conventional projection x-ray such as computed radiography (CR). Further, image processing algorithms applied to CR data have been well developed and tested for image display on film.²⁻⁵ But, little work has been done for visualization of CR images on soft-copy display, which has the potential to capitalize more fully on the digital nature of the data. The purpose of this study is to assess the utility of providing presets for CR soft-copy display, based not on the window/level settings, but on processing applied to the image optimized for visualization of specific findings, pathologies, etc (ie, pneumothorax, tumor, tube location).

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METHODS

The general objective of this research is to design, implement, and evaluate digital image processing techniques for soft-copy display of clinical computed chest radiographs. Chest projection radiographs tend to contain feature-based characteristics (ie, lines, blobs, patterns) versus cross-sectional images, which have tissue-specific characteristics. Clinical examples of feature-based findings include the sharp contrast and linear features of tubes and lines or pneumothoraces in the chest, the shadow of pneumonia, the fibrous pattern of interstitial disease, and the smooth round appearance of nodules. Image processing techniques that might enhance such features in projection radiographs include not only contrast gradation processing, but also spatial frequency processing. Traditional implementations of both spatial frequency and contrast gradation processing techniques involve pixel operations in which local intensity differences are taken into account, subject to spatial extent and region size. All spatial frequencies are affected simultaneously, improving some, while worsening others. A new method, based on the multiscale image contrast amplification technique (MUSICA),⁶ emphasizes global features independent of spatial frequency, such that subtle features can be amplified, while strong components are attenuated, invariant to feature size.

In this study, MUSICA techniques are used to create finding-specific image processing presets for digital chest projection radiographs. Processing parameter design is based not only on image contrast and brightness display values, but on image quality measures and on the application of image processing optimized for specific findings, pathologies, etc. Several common chest pathologies and related radiographic findings, including the presence of tubes and/or lines, pneumothorax, lung nodules or tumors, pneumonia, and interstitial disease, provide the clinical examples. Perceived enhancement of clinical diagnosis using the digitally processed and digitally displayed images is evaluated by thoracic radiologists.

Clinical chest images are acquired using an Agfa-Gevaert (Mortsel, Belgium) ADC 70 CR scanner located in the emergency department, and Fuji (Stamford, CT) 9000 and AC2 CR scanners located in the radiology department and used for inpatient bedside examinations. Images with pertinent findings are transferred over the PACS network to a research image processing station (Agfa PS5000) for development of the optimal image processing settings per finding. Agfa-generated CR images are converted to their pyramidal file representation consisting of the image basis function set, using the Image Research Engine via Network Entity (IRENE; Agfa) software toolkit. Fuji-generated CR images are converted to raw-unprocessed data using the KHOROS (University of New Mexico, Albuquerque) image processing programming tool builder kit.

The optimal image processing developed per finding is based on feature identification and isolation via MUSICA pyramidal file basis function analysis, and emphasis or deemphasis of specific features or combination of features using MUSICA. Algorithm tuning is done in conjunction with a thoracic

radiologist's perceived enhancement of the clinical radiographic findings. The optimal image processing is chosen per finding and sets of 50 cases of each finding are read soft copy using the finding-specific processed images, and the standard default image processing based on anatomic region alone. A side-by-side image comparison is performed on a high resolution (2,000 line by 2,500 line) dual-monitor, high brightness display station. A 5-point scale is used to rate the display processing, where -2 denotes the finding-specific processing is much preferred over the default processing; -1 denotes finding-specific processing is preferred over the default processing; 0 indicates no preference for either the finding-specific or the default processing; $+1$ denotes the default processing is preferred over the finding-specific processing; and $+2$ denotes default processing is much preferred over the finding-specific processing.

RESULTS AND DISCUSSION

The optimal image processing settings for soft-copy display have been developed for pneumothorax and lung nodules/tumors. Additional finding-specific presets are being developed for tube and/or line location, pneumonia, and interstitial disease. Simultaneously, clinical case collection is currently in progress for all five categories of findings. Subjective assessments indicate a preference for the finding-specific optimized softcopy presentation versus the standard default processing presentation. Residents and nonradiologist clinicians appear to have a stronger preference for the finding-specific soft-copy display.

A potential long-term end result of this work could be the incorporation of CR processing parameters into finding-specific button settings, providing a "preset" feature on the computer graphical user interface, enabling real-time processing at the display station. In this way, CR display presets based on image processing optimized for specific findings and pathologies may have the potential to speed reading of projection x-ray examinations on soft copy and improve diagnostic efficacy. This feature would facilitate image comparison and standardize display across examination type, clinical scenario, important key findings, and significant negatives, which may be particularly useful to the nonradiologist clinician. Providing finding-specific display presets for CR at the display station may improve confidence in and acceptance of soft-copy reading for projection radiography.

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