Analyzing the Impact of Wavelet Compression on Radioisotope Image Quality

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THE PURPOSE OF THIS STUDY was to quantitatively analyze the impact of wavelet compression on radioisotope image quality. The modulation transfer function (MTF) is the transfer characteristic to describe the resolution property of an imaging system or process. If the MTF for a certain image procedure is known, the input image can be approximated from the output. A restoration filter based on the inverse MTF was applied on the wavelet-compressed images to restore the resolution, and to enhance the signal-to-noise ratio (SNR).

MATERIALS AND METHODS

A single isotope point source was scanned by a Siemens Orbiter Gamma camera (Siemens Medical Engineering UK, Berkshire, UK). The acquisition matrix of the image was $512 \times 512 \times 8$ bits, and its MTF was calculated in Matlab 5.0 (The Mathworks, Inc, Natick, MA). The original image of the point source was compressed with the wavelet algorithm at different quality levels from 100 to 0, ie, degrees of quantification from low to high. The MTFs of these point source images characterize the resolution property at the corresponding quality levels.

A four-quadrant bar phantom was scanned at the same Gamma camera system with the same set-up. The original image of the bar phantom was also compressed with the wavelet algorithm at the same quality levels.

The wavelet-compressed bar phantom images were processed in the Fourier domain by an inverse MTF filter for the corresponding quality level. Each MTF was cut-off when it reaches 10% of its amplitude. The inverse MTF beyond the cut-off frequency was extrapolated with an exponential function in order to avoid excessive ringing artifact. The images were

Fig 1. The image of the bar phantom compressed at the quality level of 90. Note that the image appearance has been smoothed; there is no artifact observed.

Fig 2. SNR_{rms} for both compressed and restored images ($SNR_{rmsw} = SNR_{rms}$ for the compressed images; $SNR_{rmsr} = SNR_{rms}$ for the restored images).

analyzed by comparing the root-mean-square error (e_{rms}), the root-mean-square SNRs (SNR_{rms}), and the profiles drawn in the different regions of interest (ROIs).

RESULTS

Impact of Wavelet Compression

It was found that wavelet compression smooths the image in general, especially at higher quality levels (lower degrees of quantization) (see the smoothed appearance of the compressed image in Fig 1). The SNR_{rms} (see SNR_{rmsw} in Fig 2) shows a sudden peak between the quality levels of 100 to 80, and decreases gradually thereafter. Between the quality levels 100 to 70, the MTF does not differ much from that of the original image. Below the quality level 70, the MTFs are generally lower than that of the original (see three MTF curves in Fig 3). The performance of the MTFs of the compressed images are in agreement with the SNRs.

Wavelet compression causes two kinds of artifact, mainly rice and diagonal (newly observed)

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0897-1889/00/1302-1046\$10.00/0

doi:10.1053/jdim.2000.6876

Fig 3. The MTFs of compressed images at 3 quality levels of 100 (no compression), 50 and 0 (highest degree of quantization).

artifacts for both lower and higher degrees of quantization (see the diagonal artifact in Fig 4). The presence of artifacts is dependent on the degree of quantization, as well as the frequency contents of the image. As the quantization degrees of compression and the frequency components of the image increase, the diagonal artifact severely damages the clinically important details in the image and therefore sacrifices the diagnostic accuracy.

The inverse MTF filter enhances the SNR_{rms} , and as the quality levels decrease (ie, to increase the quantization), the SNR_{rms} of the restored images gradually increases (see SNR_{rms} in Fig 2).

CONCLUSION

In the higher quality levels, wavelet compression smooths the data and preserves most diagnostic

Fig 4. The image of the bar phantom compressed at the quality level of 10 (note the presence of the diagonal artifact).

information in the images. It was found that the MTF performance along with the quality levels coincides well with that of the SNRs. This demonstrated the usefulness of the MTF as a means to assess image quality in compression. However, as the quality levels decreased, the effect of the diagonal artifact became predominant such that it distorted the higher frequency components of the image. The inverse MTF filter sharpened the image and enhanced the SNR. However, in using the inverse MTF filter, one should be aware of the ringing artifact that can be reduced by extrapolating a tail part beyond the cut-off frequency of the filter.

ACKNOWLEDGMENT

The authors would like to thank the Department of Clinical Radiology, University of Bristol for hosting this research.