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# Regional variance of visually lossless threshold in compressed chest CT images: Lung versus mediastinum and chest wall☆

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**Abstract**

*Objective:* To estimate the visually lossless threshold (VLT) for the Joint Photographic Experts Group (JPEG) 2000 compression of chest CT images and to demonstrate the variance of the VLT between the lung and mediastinum/chest wall.
*Subjects and methods:* Eighty images were compressed reversibly (as negative control) and irreversibly to 5:1, 10:1, 15:1 and 20:1. Five radiologists determined if the compressed images were distinguishable from their originals in the lung and mediastinum/chest wall. Exact tests for paired proportions were used to compare the readers' responses between the reversible and irreversible compressions and between the lung and mediastinum/chest wall.
*Results:* At reversible, 5:1, 10:1, 15:1, and 20:1 compressions, 0%, 0%, 3–49% ($p < .004$, for three readers), 69–99% ($p < .001$, for all readers), and 100% of the 80 image pairs were distinguishable in the lung, respectively; and 0%, 0%, 74–100% ($p < .001$, for all readers), 100%, and 100% were distinguishable in the mediastinum/chest wall, respectively. The image pairs were less frequently distinguishable in the lung than in the mediastinum/chest wall at 10:1 ($p < .001$, for all readers) and 15:1 ($p < .001$, for two readers). In 321 image comparisons, the image pairs were indistinguishable in the lung but distinguishable in the mediastinum/chest wall, whereas there was no instance of the opposite.
*Conclusion:* For JPEG2000 compression of chest CT images, the VLT is between 5:1 and 10:1. The lung is more tolerant to the compression than the mediastinum/chest wall.


*Keywords:* Image compression; Visually lossless threshold; Chest CT; Regional variance; Lung; Mediastinum and chest wall

## 1. Introduction

The acceptable compression threshold for chest CT images depends on several independent parameters including image content, anatomical region, compression algorithm, and specific reading task [1,2]. It has been reported that the detection of lung nodules in CT images is preserved with up to 10:1 compression [3,4], however, it is uncertain from these studies if the compression level is also acceptable for the characterization of the nodules or for the detection of any potential auxiliary or coincidental findings which might be clinically important in the same CT dataset.

If a compressed image is indistinguishable from its original by radiologists, there is no basis for arguing that this *visually lossless* compression hinders any diagnostic accuracy [5]. Although the visually lossless criterion allows a relatively lower compression level, it has been gaining support as a practical guideline for medical image compression, regardless of

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image content [2,5–8]. Nevertheless, even inside an image, a regional variance of the visually lossless threshold (VLT) likely exists according to the anatomical structures. This variance becomes important in compressing images containing two or more structures of very different attributes presented in the image—for example, the lung and mediastinum or chest wall.

The purpose of this study was to estimate the VLT for the Joint Photographic Experts Group (JPEG) 2000 compression of chest CT images with a lung window setting and to demonstrate the regional variance of the VLT between the lung and the mediastinum/chest wall.

## 2. Materials and methods

Institutional review board approved this study and waived informed patient consent.

### 2.1. CT scanning

This study included 80 consecutive adult patients (24–83 years old, 49 males and 31 females) who underwent chest CT using 16-detector-row CT scanners (Brilliance; Philips Medical Systems, Cleveland, OH) during a period of 5 days in February 2006.

Scanning parameters were detector collimation, 1.5 mm; gantry rotation time, 0.5 s; tube potential, 120 kVp; and pitch, 1.19–1.25. Effective mAs ranged between 115 and 185 (mean ± S.D., 163 ± 21) using automatic tube current modulation (Dose-Right, Philips Medical Systems). The raw projection data was reconstructed into 2-mm transverse sections. A medium-sharp reconstruction algorithm (filter type C) and a matrix of 512 × 512 pixels were used. The field of view ranged between 221 and 391 mm.

In each patient, we randomly selected one image containing the lung to form an 80-image set. These images included 22 sections above the carina and 58 sections below the carina. The types of lesions contained in the images are tabulated in Table 1. This classification was based on the subjective evaluation by two body radiologists (K.H.L. and T.J.K., with 7 and 5 years of experience in body CT interpretation, respectively), who reviewed the images together after completing their visual analyses (described below). If an image contained more than two lesions, they chose the most prominent lesion in a consensus manner.

Table 1
Types of lesions in the 80 original images

| Lesion | Number of images |
|---|---|
| Normal | 33 |
| Lung | 39 |
| Focal decrease in lung attenuation | 11 |
| Nodule | 7 |
| Septal thickening | 5 |
| Ground-glass opacity | 5 |
| Bronchiectasis | 3 |
| Linear atelectasis | 3 |
| Mass | 3 |
| Dependent atelectasis | 2 |
| Pleura | 3 |
| Thickening | 2 |
| Effusion | 1 |
| Mediastinum and chest wall | 5 |
| Mastectomy | 2 |
| Aortic wall thickening | 1 |
| Rib fracture | 1 |
| Lymph node enlargement | 1 |
| Total | 80 |

### 2.2. Image compression

Each of the 80 original images had a bit depth of 12 bits per pixel packed into two bytes. Using a JPEG2000 algorithm (Pegasus Imaging Co., Tampa, FL), each original image was compressed to five different levels: a reversible (as negative control) and irreversible 5:1, 10:1, 15:1 and 20:1. These compressed images were then decompressed, yielding 400 compressed (and then decompressed) images for comparison with their originals. For the irreversible compressions, the JPEG2000 encoder parameters were set to the default settings: irreversible 9-7 wavelet filter; single tile; 6 levels of wavelet decomposition; code-block, 64 × 64; precinct, 32,768 × 32,768; and a single layer. The actual compression levels (the ratio of original 16 bits/pixel to compressed size in bits/pixel) achieved for the four irreversible compressions were 5.00 ± 0.02 (mean ± S.D.), 10.01 ± 0.05, 14.98 ± 0.12, and 20.00 ± 0.13, respectively. These variations from the nominal levels were considered unimportant in this study. Window level and width were fixed at a lung setting, −600 and 1500 HU, for the subsequent analyses.

### 2.3. Visual analysis

Five board-certified body radiologists (including Y.H.K., T.J.K., and K.H.L.) participated in the analysis. They had 4–8 years (4, 5, 5, 7, and 8 for readers 1–5, respectively) of working experience in interpreting body CT.

Each of the 400 compressed images was paired with its original for visual comparison. The 400 image pairs were randomly assigned to eight reading sessions, while avoiding the repetition of any patient in a session. The order of reading sessions was changed among readers. Sessions were separated by a minimum of 1 week.

Each image pair was alternately displayed on a single monitor, while the order of the original and compressed images was randomized. By selectively toggling between the two images and returning to the first image as desired, each reader, who was blinded to the compression levels, independently determined if the two images were distinguishable (or, if there was any perceivable artifact in the compressed image) inside the lung region. When making comparisons, the reader was asked to pay attention to structural details (particularly the small airways, pulmonary vessels, interlobular septa, and interlobar fissures) and the texture of pulmonary parenchyma. The same analysis