The Effect of Lossy Discrete Cosine Transform Compression on Subtle Bone Fractures
Morankinyo Oyewole Toney, Rodrigo Dominguez, Huu-Ninh Dao, and Gary Simmons

Extensive research efforts have been devoted to the feasibility of picture archiving and communication systems (PACS) in recent years. The advantages of PACS are numerous but mainly include reduced cost and improvement in the operational efficiency of a PACS-based radiology department. In digital radiography, images are viewed either in hard-copy or soft-copy format. Usually, these images are subsequently compressed and archived for future evaluation. There are various methods used in image compression. In this study, computed radiography images showing subtle pediatric bone fractures were compressed with the lossy method of image compression after they had been initially evaluated on workstation monitors. These studies were subsequently evaluated by observers, who were unaware of the interpretations of these images before compression, to determine if they could detect similar abnormalities. Our conclusion is that there is no difference in the interpretation of soft-copy computed radiographic images before or after lossy 10:1 compression in studies of subtle pediatric bone fractures. This is a US government work. There are no restrictions on its use.

KEY WORDS: computed radiography, lossless and lossy compression, hard-copy, soft-copy, Friedman analysis of variance (ANOVA), Wilcoxon's signed ranked test.

IN RECENT YEARS, extensive research and development efforts have been devoted to the feasibility of picture archiving and communication systems (PACS) as a replacement for film-based radiography.1-6 Unlike teleradiology in which images are transmitted to remote areas, PACS is used for local transmission of images, usually within the hospital and imaging centers.4 There are numerous advantages to the PACS in radiology. These include reduced storage space requirements, and film cost, expedient image transfer and display of radiographic images, and overall improvement in the operational efficiency of PACS-based radiology departments.5

Digital images are potentially available to radiologists in two viewing forms when using computed radiography (CR): hard-copy and soft-copy.7-9 In hard-copy viewing, digital data is used to modulate the intensity of a laser beam that exposes an analog film. Soft-copy viewing involves the conversion of digital data to an analog video signal that is viewed on a preview monitor or multimonitor workstation in a stand-alone or networked situation. In this study, images were displayed in soft-copy on workstations incorporating four monitors each with a 1536 × 2048 pixel matrix.

There are several advantages to the use of image compression in CR. These include decreased short-term magnetic and long-term optical media requirements, increased speed of transmission, and decreased transmission cost in PACS and teleradiology. The goal of the study was to assess the efficacy of using soft-copy CR images in detection of subtle pediatric bone fractures before and after lossy 10:1 compression (Figs 1 and 2).

METHODS

A total of 67 pediatric plain CR images of the upper or lower extremities, such as the elbows, wrists, hands, or ankles, referred to the radiology department from the emergency room were evaluated on PACS workstations.

This study was conducted by using the Department of Defense's Medical Diagnostic Imaging Support (MDIS) PACS (Medical Imaging System Vantage PACS; Lockheed Martin, La Jolla, CA) at our institution. This system incorporates a CR subsystem (ST-V; Fuji, Kanagawa, Japan) with images displayed as soft-copy on workstations incorporating four monitors each with a 1536 × 2048 pixel matrix supported by Infodex (Model No. GMA-212; Wolcott, CT). These monitors allow the radiologists to digitally manipulate images using a mouse and keyboard commands. Images can be magnified, minified, the gray scale inverted, and the image contrast (window and level) adjusted as a minimum.

Initially, these digital soft-copy images were individually interpreted before compression by two radiologists with at least two years of experience with the functions of the PACS workstation. After the images were compressed with a 10:1 lossy compression technique, they were subsequently individually interpreted by two other experienced radiologists with at least one year of experience with the PACS workstation and who were unfamiliar with the previous interpretations.2 Thirty-two of
the 67 cases were reported as fractures, ie, torus, buckle, or Salter I fractures. Another 32 were reported as normal, and 3 studies were found technically inadequate for interpretation.

The radiographic diagnosis grading system used was as follows: (1) definite fracture, (2) no fracture, (3) probable fracture, and (4) indeterminate image for interpretation. Statistical analysis of the results of interpretation before and after application of lossy compression was performed by means of Friedman nonparametric repeated analysis of variance (ANOVA) and Wilcoxon's signed rank test statistical analysis.10 Using the data obtained, a power analysis was performed to estimate the power of this study to detect a difference between compressed and uncompressed images. The sensitivity of uncompressed images was estimated to be 90%. The methods of Kraemer and Thiesmann11 and Fleiss12 were used to estimate the number of subjects needed to detect a difference in sensitivity and specificity with a level of confidence of 95% and a power of 80%. Next, 1,000 iterations of Monte Carlo simulation were performed to determine the power using the estimated number. If the power was less than 80% or greater than 85%, the number was modified proportionately and the 1,000-run Monte Carlo simulation was reiterated until a power ranging from 80% to 85% was obtained. According to this method, 33 images were sufficient to detect a change in sensitivity from 0.90 to 0.55 with the desired level of confidence and power.

RESULTS

The Friedman nonparametric ANOVA showed that no significant difference exists between observers before and after compression of the images (Table 1). Also, the Wilcoxon’s signed ranked test showed no significant differences between observers before and after image compression (Table 2).

Five studies were initially classified as probable fracture by all observers. These were subsequently combined into the fracture group because the initial clinical management was similar and follow-up images in these 5 studies were consistent with fracture. The clinical management and course of these patients was the “gold standard” used to confirm a radiologist’s interpretation of fractures. Observers were not aware of the clinical outcome of cases until all images were interpreted (before or after compression). Combining definite fractures and probable fractures into one category, because the initial clinical management was similar, showed no statistical difference in classification relative to compression.

Table 1. Friedman Nonparametric Repeated ANOVA Measures in 67 Cases

<table>
<thead>
<tr>
<th>Mean Rank</th>
<th>Compression</th>
<th>Observer</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.57</td>
<td>Before</td>
<td>1</td>
</tr>
<tr>
<td>2.57</td>
<td>Before</td>
<td>2</td>
</tr>
<tr>
<td>2.49</td>
<td>After</td>
<td>3</td>
</tr>
<tr>
<td>2.37</td>
<td>After</td>
<td>4</td>
</tr>
</tbody>
</table>

Note: Before, images interpreted by observers 1 and 2 before compression; After, images interpreted by observers 3 and 4 after compression.

*p = .7573, χ² = 1.1821, DF = 3.