Clinical Evaluation of Irreversible Data Compression for Computed Radiography of the Hand

Kazuhiko Uchida, Hideyuki Watanabe, Takatoshi Aoki, Katsumi Nakamura, and Hajime Nakata

We evaluated the clinical utility of high data compression for computed radiography (CR) of the hand. Paired original and compressed CR images were obtained using an FCR 9000 system in 35 patients with various abnormalities of the hand. For the paired original and compressed images, we compared the depiction of the bone cortex, bone trabeculae, soft-tissue, and the margin of the abnormalities. The overall impressions for detectability of the abnormalities and for diagnostic capability were also evaluated. Poorer image quality of the compressed images was noted for most of the structures, but there was no significant difference between the original and compressed images as for the overall impressions for detectability of the abnormalities or for diagnostic capability. We conclude that a high data compression may be clinically acceptable with caution in radiography of the hand.

Copyright © 1998 by W.B. Saunders Company

KEY WORDS: computed radiography (CR), data compression, hand, bone.

COMPUTED RADIOGRAPHY (CR) has become widely used in radiographic examinations of various parts of the body owing to its advantage as a digital system. However, the amount of data needed for CR is rather large. One CR image usually requires 4 to 6 Mbytes of data, and the storage and transfer of this amount of raw data is difficult. High data compression without loss of diagnostic capability is desirable, and a compression ratio of at least 20:1 is currently available and in use. Studies on the clinical applicability of high data compression have been reported for CR of the chest,¹⁻⁵ breast,⁵ gastrointestinal tract,⁶ and urinary tract.⁷ The use of CR for evaluation of the skeletal system was delayed until its recent clinical acceptance mainly because its spatial resolution in this body system was considered to be insufficient compared with that of the film-screen system.⁸⁻¹² Accordingly, there has been no report regarding the application of data compression for skeletal CR. This study was conducted to evaluate the usefulness of high data compression by using the Type III technique of an FCR 9000 system (Fuji Photo Film, Tokyo, Japan) in radiography of the hand. This Type III data compression based on prediction and Huffman coding is an irreversible technique and provides compression ratio of approximately 20:1 to 25:1.³

MATERIALS AND METHODS

CR images of the hand were obtained by using an FCR 9000 system with a 25.2 × 30.3 cm ST-V imaging plate (1670 × 2010 matrix, pixel size 150 μm, 10 bits). The exposure factors were 44 kV and 200 mA with 0.02 second, and the source-to-image distance was 100 cm. The standard processing parameters for bone were used. Life-size hard copies were produced using a laser printer (FL-IMD, Fuji Photo Film, Tokyo, Japan).

The images acquired in 35 patients with abnormalities of the hand were selected from the file of CR images radiographed between January and December, 1996. The selection was made to cover a wide age range and to include subtle cortical abnormality. There were 14 men and 21 women whose ages ranged from 9 to 82 years (mean age, 46.1 years).

Their diagnoses were as follows: linear fracture in 11, rheumatoid arthritis and related disease in 11, secondary hyperparathyroidism in 10, aseptic necrosis of the lunate in 2, and enchondroma in 1. Except for the patient with enchondroma, which was histologically confirmed following surgery, they were diagnosed on the basis of their clinical symptoms, laboratory data, and radiographic findings.

A pair of hard copies of original images and images reconstructed using Type III compression was made for each patient. The images were evaluated by direct comparison by 4 certified radiologists. Each pair of original and compressed images was compared individually for depiction of bone cortex, bone trabeculae, soft-tissue, and margin of abnormalities. The overall impressions for detectability of the abnormalities and for diagnostic capability were also evaluated. The radiologists were not aware of which one of the pair was the original or compressed image, but they were aware of the diagnosis in each patient (Table 1). The results were rated as follows: (1) original much better than compressed image, (2) original better than compressed image, (3) original equal to compressed image, (4) compressed better than original image, and (5) compressed much better than original image. Statistical evaluation was performed using the χ^2 test.

RESULTS

The total numbers of observations with each rating by the radiologists are shown in Table 1. There were only a few image pairs with a rating of (1), and none with a rating of (4) or (5). The bone cortex, bone trabeculae, and margin of abnormalities, but not the soft-tissue, were rated as signifi-

From the Department of Radiology, University of Occupational and Environmental Health, Yahatanishi-ku, Japan.

Address reprint requests to Hajime Nakata, MD, Department of Radiology, University of Occupational and Environmental Health, Yahatanishi-ku, Kitakyushu-shi 807, Japan.

*Copyright © 1998 by W.B. Saunders Company
0897-1889/98/1103-0003\$8.00/0*

Table 1. Given Xn Number of Observations, Score Comparison Between Compressed and Original CR Image of Hand

	No. of Observations				
	(1) Original much better	(2) Original better	(3) Equal	(4) Compressed better	(5) Compressed much better
Target points					
Bone cortex*	2	58	80	0	0
Bone trabeculae*	6	94	40	0	0
Soft tissue**	0	1	139	0	0
Margin of abnormalities*	0	60	80	0	0
Overall impression					
Detectability of abnormalities**	0	11	129	0	0
Diagnostic capability**	0	13	127	0	0

*Significant difference between original and compressed images.

**Insignificant difference ($P < .05$) between original and compressed images.

cantly better depicted on the original image than on the compressed image ($P < .05$). There was no significant difference between original and compressed images regarding the overall impressions for detectability of the abnormalities and for diagnostic capability ($P < .05$). Representative image sets are illustrated in Figs 1 to 4.

DISCUSSION

Because of the currently increasing acceptance of CR of the skeletal system, we considered it important to examine the clinical applicability of high data compression in this body system. Our previous studies³⁻⁷ of this Type III high data compression technique showed its clinical useful-

Fig 1. Linear fracture of metacarpal. (A) Original image. (B) Compressed image. The bone trabeculae and the margins of abnormalities were rated as "original better than compressed image" by all 4 observers, and the bone cortex as such by 2 of them. The overall impressions for detectability of the abnormalities and for diagnostic capability were rated as "original equal to compressed image" by all of the observers.

Fig 2. Rheumatoid arthritis with erosions and narrowing of joint space in proximal interphalangeal and metacarpophalangeal joints. (A) Original image. (B) Compressed image. Only the bone trabeculae were rated as "original better than compressed image" by all of the observers. The overall impressions were rated as "original equal to compressed image" by all.

ness in the chest and gastrointestinal tract radiographies and excretory urography.

Although there was a slight deterioration of the image quality of the compressed images, we did not find the diagnostic information to be diminished in these examinations. Only in mammography was the reduced detectability of diagnostically important microcalcifications of this high data compression clinically unacceptable.⁵

We chose the hand as a representative component of the skeletal system because the fine structures such as the bone trabeculae, bone cortex, and small arthritic changes can be observed. All anatomical structures excluding soft-tissue were significantly better depicted on the original image than on the compressed image. The bone trabeculae were particularly poorly depicted on the compressed image. The degradation of the image quality by fine linear opacity when high data compression technique is applied was reported for chest CR.¹⁻³ This also seems to occur in the imaging of bone trabeculae consisting of fine linear structures. The detection of subperiosteal bone resorption in hyper-

parathyroidism can be difficult when the images have pixel size of more than 80 μm , and CR may be inferior to film-screen image in diagnosing minor trauma.^{13,14} The imaging plate currently in use has a pixel size of 150 μm , and in this Type III compression technique 4 adjacent pixels of 150 μm size are averaged before the processes of compression.³ Therefore the degradation of image quality is at present unavoidable and is particularly conspicuous for fine linear structures such as the bone trabeculae and bone cortex.

Regarding the overall impressions for detectability of the abnormalities and for diagnostic capability, we found no significant difference between the original and the compressed images. Thus, the image quality degradation resulting from compression does not seem marked enough to make this method totally unacceptable. In our study the diagnoses were known to the observers and this may have influenced their observations of the images. The use of compressed images such as these for the initial diagnostic evaluation is problematic. The obviously poorer image quality in visual-

Fig 3. Hyperparathyroidism with osteopenia and subperiosteal bone resorption in middle phalanges. (A) Original image. (B) Compressed image. All 4 observers rated the one trabeculae, bone cortex and margin of abnormalities as "original much better or better than compressed image." Two of the observers rated the overall impressions as "original better than compressed image."

Fig 4. Enchondroma of middle phalanx. (A) Original image. (B) Compressed image. The bone trabeculae and margin of abnormalities were rated as "original better than compressed image" by all 4 observers, and the bone cortex as such by 2 of them. The overall impressions were rated as "original equal to compressed image" by all.

izing the bone trabeculae and bone cortex on compressed images may make the diagnosis of subtle periosteal reaction and cortical irregularity difficult and may reduce the diagnostic capability.

Therefore, the use of this compression technique in the imaging of the skeletal system may be limited to the storage and transfer of data after the diagnoses are established based on the original images.

REFERENCES

1. Ishigaki T, Sakuma S, Ikeda M, et al: Clinical evaluation of irreversible image compression: Analysis of chest imaging with computed radiography. *Radiology* 175:739-743, 1990
2. MacMahon H, Doi K, Sanada S, et al: Data compression: Effect on diagnostic accuracy in digital chest radiography. *Radiology* 178:175-179, 1991
3. Mori T, Nakata H: Irreversible data compression in chest imaging using computed radiography: An evaluation. *J Thorac Imaging* 9:23-30, 1994
4. Kido S, Ikezoe J, Kondoh H, et al: Detection of subtle interstitial abnormalities on digital chest radiographs: acceptable data compression ratios. *AJR Am J Roentgenol* 167:111-115, 1996
5. Murakami S, Oda N, Terada E, et al: Data compression for chest radiography and mammography using computed radiography. *Nippon Igaku Hoshasen Gakkai Zasshi* 51:13-18, 1995
6. Uchida K: Evaluation of data compression in gastrointestinal examinations using computed radiography. *Nippon Igaku Hoshasen Gakkai Zasshi* 56:482-489, 1996
7. Uchida K, Nakamura K, Watanabe H, et al: Clinical evaluation of irreversible data compression for computed radiography in excretory urography. *J Digit Imag* 9:145-149, 1996
8. Fujita S, Tanaka M, Hirota S, et al: Clinical application of computed radiography in orthopedic surgery. *J Digit Imag* 8:51-60, 1995
9. Jonsson A, Henneson P, Herrlin K, et al: Computed vs film-screen magnification radiography of fingers in hyperparathyroidism. An ROC analysis. *Acta Radiol* 36:290-294, 1995
10. Britton CA, Gabriele OF, Chang TS, et al: Subjective quality assessment of computed radiography hand images. *J Digit Imag* 9:21-24, 1996
11. Lindhardt FE: Clinical experiences with computed radiography. *Eur J Radiol* 22:175-185, 1996
12. Swee RG, Gray JE, Beabout JW, et al: Screen-film versus computed radiography imaging of the hand: a direct comparison. *AJR Am J Roentgenol* 168:539-542, 1997
13. Murphey MD: Digital skeletal radiography: spatial resolution requirements for detection of subperiosteal resorption. *AJR Am J Roentgenol* 152:541-546, 1989
14. Wilson AJ, Mann FA, Murphy Jr WA, et al: Photostimulable phosphor digital radiography of the extremities: Diagnostic accuracy compared with conventional radiography. *AJR Am J Roentgenol* 157:533-538, 1991