

## Technical Note

# Subtracted Synthetic Images in Gd-DTPA Enhanced MR

Yuji Suto, Biray E. Caner, Yoichi Tamagawa, Tsuyoshi Matsuda, Issyu Kimura, Hirohiko Kimura, Takashi Toyama, and Yasushi Ishii

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**Abstract:** The evaluation of Gd-DTPA contrast enhancement (CE) in high intensity tissues on T1-weighted magnetic resonance images, such as fat and bone marrow, is quite difficult. In this study, we used subtraction and subtracted color images in an attempt to show more clearly the Gd-DTPA CE. In addition, we also carried out sequential post-Gd-DTPA imaging to assess the changes in enhancement of lesions with time. Twenty patients were studied with these methods and our results are illustrated. **Index Terms:** Magnetic resonance imaging, techniques—Contrast media—Gadolinium.

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Gadolinium-DTPA has been proven to be an effective contrast enhancing agent in magnetic resonance (MR) imaging without any significant side-effects (1-3). It shortens T1 and T2 values of tissues in which it localizes, resulting in high signal intensity on T1-weighted images (T1WI). However, the evaluation of Gd-DTPA contrast enhancement (CE) in high signal intensity tissues on T1WI may be quite difficult. In this report we describe our method of generating subtraction, hybridized, and subtracted synthetic MR images, which can facilitate the visualization and anatomical localization of abnormal Gd-DTPA enhancement. Furthermore, the time sequence of signal intensity changes induced by Gd-DTPA was studied to determine if the temporal analysis could offer additional information on the tissues under investigation.

### MATERIALS AND METHODS

All MR images were performed on a 0.35 T superconducting magnetic system (Resona, Yokogawa Medical). The spin echo T1WI of the area to be studied were obtained before and then sequentially up to 40 min after Gd-DTPA injection,

with a repetition time (TR) of 400 ms and an echo time (TE) of 35 ms. A 10 mm section thickness, 192 × 192 matrix, 35 cm field of view, and fourfold signal averaging were used. Gadolinium-DTPA 0.05 mmol/kg (Nihon Schering) was injected for contrast enhanced MR studies. The data obtained were transferred to a computer system (Vax 11/750; DEC Co.) and the image processing as well as display were performed by means of a real time image processor (Nexus 6400).

The three main steps of image processing (Fig. 1) are as follows: (a) A subtraction image was obtained by subtracting the precontrast original T1WI from the postcontrast image. (b) A hybridized image was obtained by superposition of the original T1WI on the subtracted image that was obtained by gradation processing. (c) The subtracted synthetic image was obtained by the RGB additive color mixing method (4,5) (Fig. 2). The hybridized image was displayed in red memory, while the original T1WI was displayed in blue as well as in green memory. After color mixture processing, a subtracted synthetic image was generated in which the enhanced areas were represented in red and the nonenhanced areas in white.

A total of 20 patients, 15 male and 5 female (16-70 years old), were studied. The pathologies included soft tissue tumors (n = 6), bone tumors (n = 6), aseptic bone necrosis (n = 4), cervical cancer (n = 1), ovarian cancer (n = 1), and osteomyelitis (n = 1). Two representative cases are illustrated.

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From the Department of Radiology, Fukui Medical School, Matsuoka-cho, Yoshida-gun, 910-11 Fukui, Japan. Address correspondence and reprint requests to Dr. Y. Suto.

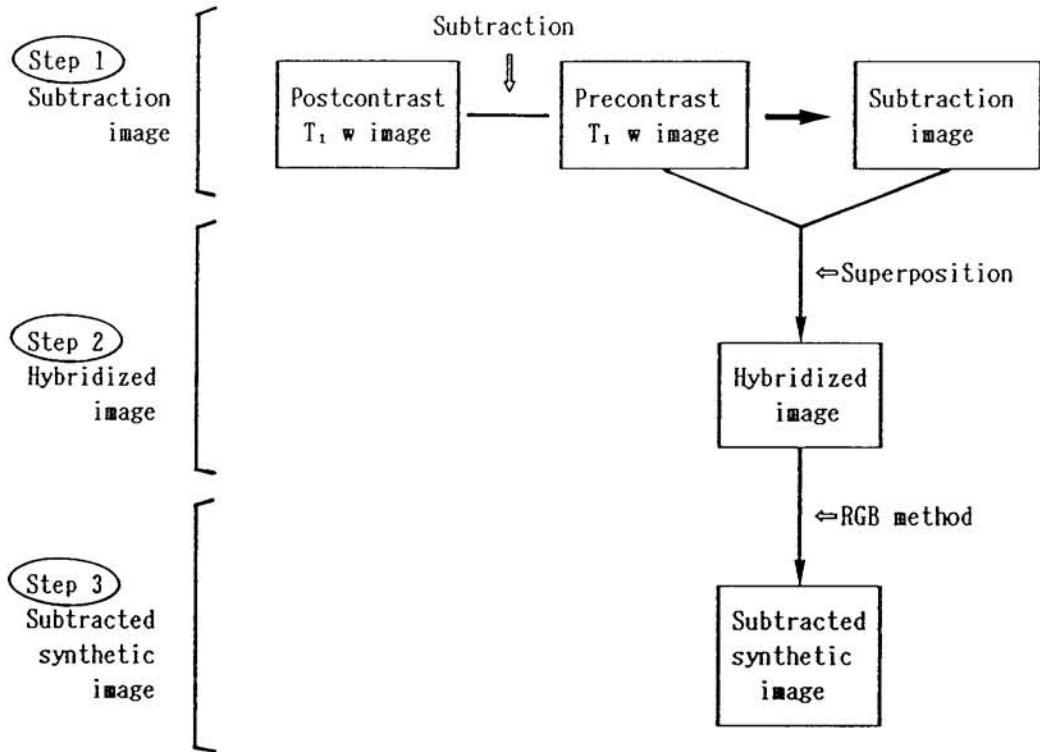


FIG. 1. Schematic illustration of the method.

CASE REPORTS

Case 1

A 16-year-old boy had an osteoid osteoma of the femur. The precontrast T1WI showed a cortical thickening of the

right femoral shaft (Fig. 3a). A focus of high signal intensity was seen in the thickened cortex. This area corresponded to the nidus demonstrated on X-ray. A T2WI (TR 1,500/TE 70 ms) did not reveal additional abnormalities (Fig. 3b). On the postcontrast unprocessed T1WI taken 10 min after Gd-DTPA injection, CE of the tumor

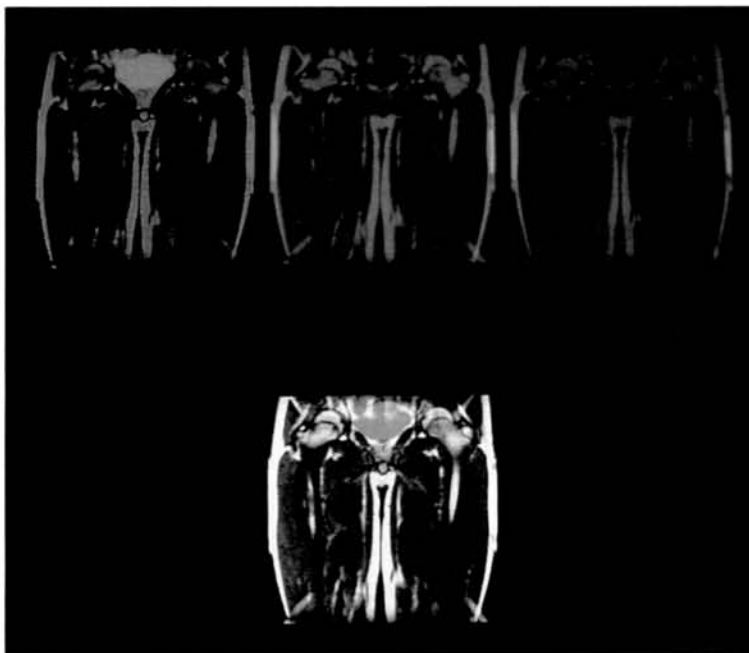
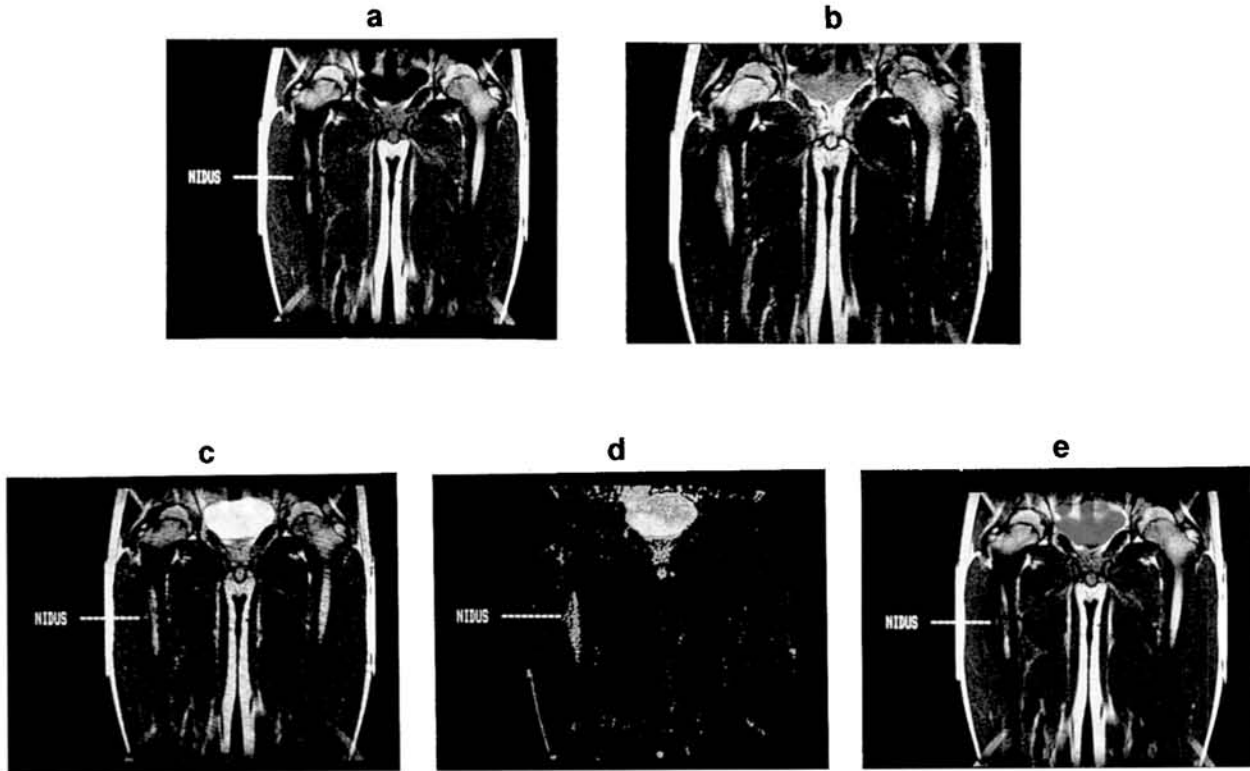


FIG. 2. Generation of subtracted synthetic image by the RGB additive color method. The hybridized image is displayed in red memory (top left) and the unprocessed precontrast T1WI is displayed in green and in blue memory (top middle and right). After a superposition procedure, the subtracted synthetic image (bottom) is generated. The contrast enhanced areas are seen in red, facilitating their visualization.



**FIG. 3.** Case of osteoid osteoma of the right femur. **a:** Precontrast T1WI. **b:** T2WI. **c:** Postcontrast unprocessed T1WI. **d:** Subtracted T1WI. **e:** Subtracted synthetic T1WI. Note that Gd-DTPA enhancement of the nidus and of surrounding bone marrow is more evident in (d) and (e).

was not very clear (Fig. 3c). The corresponding subtraction image of the same area more clearly showed the CE of the nidus as well as some parts of the bone marrow adjacent to the nidus (Fig. 3d). On the subtracted synthetic image, in which the subtracted image was superposed onto the original image and colored by the RGB method, the spatial relationship of the abnormally enhanced areas was better displayed (Fig. 3e). In particular, the CE of the bone marrow adjacent to the nidus was more obviously shown in red.

### Case 2

A 50-year-old man was diagnosed as having chronic osteomyelitis of the right tibia. Figure 4 shows the subtracted synthetic image of this patient. The CE of the involved area seen was clearly visible in red. The precontrast T1WI and the postcontrast sequential T1WI taken every 5 min up to 15 min after Gd-DTPA injection (right column) and their corresponding subtracted synthetic images (left column) are demonstrated in Fig. 5. A gradual increase in CE with time was seen more clearly on the sequential subtracted synthetic images than on the originals.

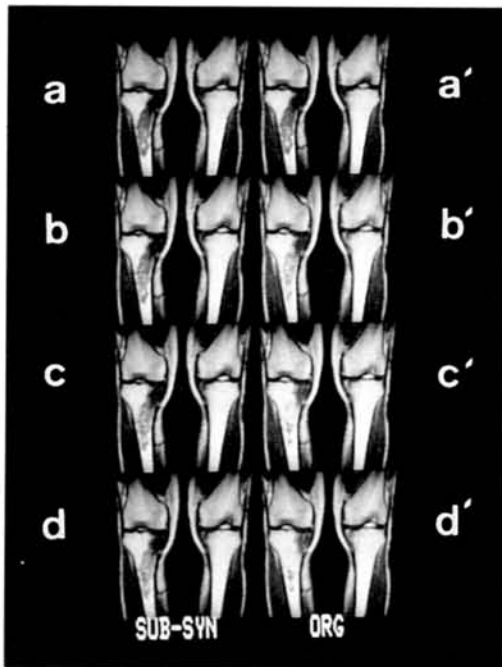
### DISCUSSION

Although Gd-DTPA is a widely used contrast medium for MR imaging, the enhancement generated

by it within high intensity areas on the T1WI may be hard to evaluate. To overcome this difficulty, we have described a method of image processing and display using subtraction and RGB additive color method.



**FIG. 4.** Chronic osteomyelitis of the right tibia: subtracted synthetic image. Note clear enhancement of the involved area and normal left tibia.



**FIG. 5.** Precontrast and sequential series of postcontrast T1WI of the same case as in Fig. 4. **Left column:** Subtracted synthetic images of both knees prior to (a) and 0–5 (b), 5–10 (c), and 10–15 (d) min after intravenous Gd-DTPA injection. **Right column:** Corresponding unprocessed original images (a'–d'). Note prominent enhancement of osteomyelitic right tibia area in postcontrast subtracted synthetic images (a–d).

The subtraction images highlight the differences between enhanced and nonenhanced tissues. The subtracted synthetic color images facilitate the localization and extent of CE.

In addition to the morphologic aspects of Gd-DTPA enhancement, we also studied its temporal features by serial scans taken at every 5 min up to 40 min post Gd-DTPA injection.

In conclusion, the usage of subtraction and subtracted synthetic images in conjunction with Gd-DTPA enhancement may offer additional morphological information. Temporal evaluation of the Gd-DTPA enhancement may be helpful in elucidating the functional status of the tissues under investigation.

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