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Use of Short Inversion Time Inversion Recovery Imaging to Differentiate between Aplastic Anemia and Myelodysplastic Syndrome

Koichi HIRAO[1)], Makoto OCHI[2)], Masataka UETANI[2)] and Tetsuji YAMAGUCHI[2)]

1) Department of Radiology, Sasebo Chuo Hospital, 15 Yamatocho, Sasebo 857-11, Japan

2) Dapartment of Radiology, Nagasaki University School of Medicine, 1-7-1 Sakamoto, Nagasaki 852, Japan

The value of short inversion time inversion recovery (STIR) imaging in differentiating patients with aplastic anemia (AA) from those with myelodysplastic syndrome (MDS) was investigated. Thirty-nine patients with pancytopenia were diagnosed hematologically as having AA or MDS. These patients and 95 volunteers without hematologic disorders were then examined with STIR imaging. Hyperintense posterior pelvis was present in 25 of the 29 patients with MDS, including 17 of the 19 patients with refractory anemia. In contrast, high intensity of the posterior pelvis was absent in 8 of the AA 10 patients. High intensity of the femoral elements was present in 6 of the 8 patients with severe MDS and 3 of the 19 patients with refractory anemia. High intensity in the femoral elements was absent in all 10 AA patients. STIR imaging was useful in differentiating patients with AA from those with MDS.

Introduction

The signal intensity observed with magnetic resonance (MR) imaging of the bone marrow reflects hematopoietic function and cellularity[1]. Findings of normal marrow conversion and bone marrow disease using standard spin echo sequences have been well described[2-10]. Short inversion time inversion recovery (STIR) detects and characterizes hematopoietic disorders[11-16]. To our knowledge, only one report regarding normal marrow conversion investigated by STIR has been published[17]. In the present study, we determined the marrow signal intensity (MSI) pattern of the pelvis and femora in normal adults using STIR and investigated the potential value of STIR imaging in differentiating patients with aplastic anemia (AA) from those with myelodysplastic syndrome (MDS).

Materials and Methods

Ninety-five volunteers were investigated by MR imaging. There were 41 men, ranging in age from 25 to 67 years (mean, 43.7 years), and 54 women, ranging in age from 25 to 69 years (mean, 43.7 years). They had no evidence of disease that could affect marrow conversion and showed normal results of complete blood counts. Histological confirmation was not available in these volunteers.

The MR findings of 39 patients, 10 with severe AA and 29 with MDS, were retrospectively reviewed. Pathological diagnosis was made by bone marrow biopsy of the sternum in all patients. The AA patients were 5 men and 5 women, ranging in age from 17 to 70 years (mean 51.4 years). The MDS patients were 15 men and 14 women raging in age from 16 to 75 years (mean, 50.7 years). Among the 29 patients with MDS, 19 were diagnosed as having refractory anemia (RA), 2 had RA with ringed sideroblasts (RARS), 5 had RA with excess of blasts (RAEB), 1 had RAEB in transformation (RAEB-T), and 2 had chronic myelomonocytic leukemia (CMMoL), according to the French-American-British group classification (Table 1)[18]. Six patients with AA (cases 2, 4-7, and 9) and 8 patients with RA (cases 13-17, 21, and 25) had been treated prior to MR examination.

All MR studies were performed using a 1.5-T unit (Signa ; GE Medical Systems, Milwaukee, WI, USA). These studies included coronal STIR imaging [2000/20/160/2 (repetition time/echo time/inversion time/excitations)], using 5 mm section thickness with a 2.5 mm intersection gap and a field of view of 35 cm with a matrix of 256*128.

The pelvis and femora were divided into eight anatomical regions : the pubis, anterior ilium, posterior ilium, ischium, acetabulum, femoral neck, intertrochanteric region, and proximal femoral diaphysis. The epiphyseal cap of the femur was not evaluated in this study. A coronal section through the center of the femoral heads was used to divide the ilium into the anterior and the posterior.

A visual evaluation of the MSI pattern in each region was then made. The MSI patterns on STIR images were divided into four grades according to the following criteria : grade H-d, diffuse high intensity, hyperintense or isointense relative to adjacent muscles ; grade H, focal high intensity foci, hyperintense or isointense relative to adjacent muscles; grade M, focal intermediate intensity

Table 1. Clinical diagnosis and marrow signal intensity in the patients with aplastic anemia and myelodysplastic syndrome

Case/Age/Sex	Type of Disease	Marrow Signal Intensity				Therapy prior to MR
		Ant. Pelvis	Post. Pelvis	Femoral Elements	Femoral Diaphysis	
1/17/F	AA	M	M	M	H	N.D.
2/17/F	AA	H	L	L	L	Done
3/41/M	AA	H	L	L	L	N.D.
4/54/M	AA	H	H	L	H	Done
5/58/M	AA	L	L	L	L	Done
6/59/F	AA	H	H	L	H	Done
7/65/F	AA	L	L	L	L	Done
8/66/F	AA	L	L	L	H	N.D.
9/67/M	AA	L	L	L	M	Done
10/70/M	AA	L	L	L	L	Done
11/16/F	RA	H-d	H-d	H	H	N.D.
12/16/F	RA	H	H	L	H	N.D.
13/17/F	RA	H-d	H	L	H	N.D.
14/23/F	RA	H-d	H-d	L	M	Done
15/31/F	RA	L	L	L	H	Done
16/34/F	RA	H	H-d	L	H-d	Done
17/39/M	RA	H	H	L	H-d	Done
18/39/M	RA	H	L	L	H	Done
19/45/F	RA	H	H	L	L	N.D.
20/55/F	RA	H-d	H	L	L	N.D.
21/58/M	RA	H	H	H	H	N.D.
22/58/F	RA	L	H	L	H	Done
23/62/M	RA	M	H	L	H	N.D.
24/63/M	RA	H	H	L	H-d	N.D.
25/67/M	RA	H	H	L	M	Done
26/67/M	RA	H	H	L	L	N.D.
27/69/F	RA	H	H	L	H	Done
28/70/F	RA	H	H	L	H	N.D.
29/75/M	RA	H	H	L	H	N.D.
30/55/M	RARS	H	H	L	H-d	N.D.
31/73/M	RARS	H-d	H-d	H	H-d	N.D.
32/55/M	RAEB	M	M	L	H-d	N.D.
33/57/F	RAEB	H	H	M	H	N.D.
34/62/M	RAEB	H-d	H-d	H-d	H-d	N.D.
35/63/M	RAEB	H	H-d	H-d	H-d	N.D.
36/67/F	RAEB	H-d	H-d	H-d	H-d	N.D.
37/62/M	RAEB-T	M	M	H	H	N.D.
38/21/M	CMMoL	H-d	H-d	H-d	H-d	N.D.
39/50/F	CMMoL	H-d	H-d	H-d	H-d	N.D.

1) Anterior pelvis = anterior ilium and pubis
2) Posterior pelvis = posterior ilium, ischium, acetabulum
3) Femoral elements = femoral neck and intertrochanteric region of the femur
4) N.D. = not done

foci, hypointense relative to adjacent muscles, hyperintense relative to adjacent fat ; grade L, diffuse low intensity, isointense relative to adjacent fat (Fig. 1).

After the analysis of the loco-regional MSI patterns in the normal volunteers, the MSI patterns of the patients were compared with those of the normal volunteers. Finally, the MSI patterns in each anatomical region of the patients with AA were compared with those of the patients with MDS. Statistical analysis was done using the chi 2 test.

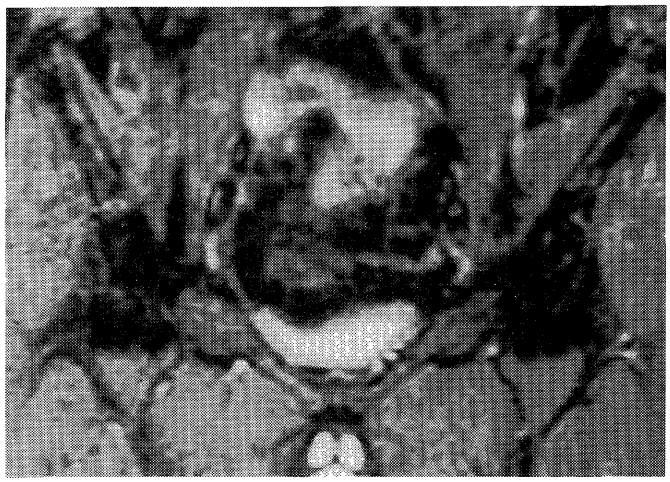

Fig. 1-A

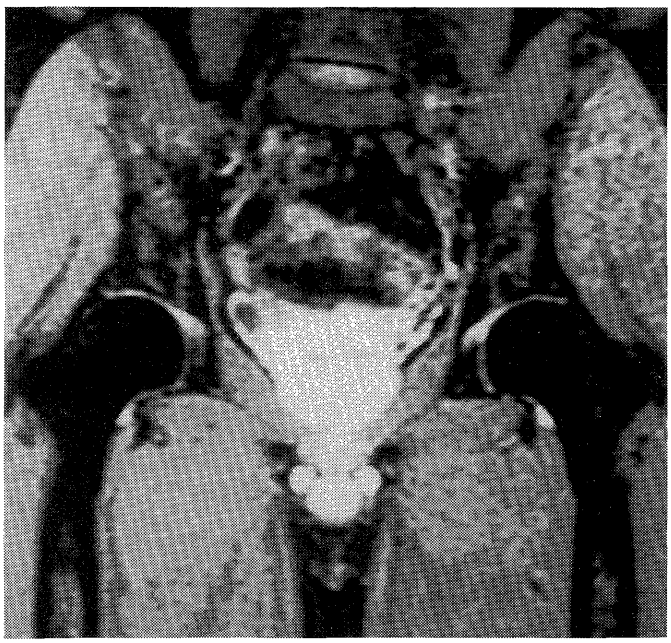

Fig. 1-B

Figure 1. A 43-year-old male volunteer, short inversion time inversion-recovery (STIR) coronal images. (A) The anterior ilium and pubis show grade H. (B) The posterior ilium, acetabulum and intertrochanteric region of the femur show grade M, the proximal femur shows grade H, and the femoral neck shows grade L.

Results

The loco-regional MSI patterns in the male and female volunteers are shown in Figs. 2 and 3, respectively. The eight anatomic regions were classified into four groups on the basis of MSI pattern : anterior pelvis (anterior ilium and pubis), posterior pelvis (posterior ilium, ischium, and acetabulum), femoral elements (femoral neck and intertrochanteric region), and proximal femoral diaphysis.

In the normal male subjects, grade H-d was not present in any region. Grade H was present in 17 of the 41 images of the anterior pelvis, and 3/41 of the posterior pelvis. Grade H was absent in the femoral elements. Grade M was present in 24 of the 41 images of the anterior pelvis, 38/41 of the posterior pelvis, and 35/41 of the femoral elements. Grade L was present in the femoral elements only ; 4/41 of the intertrochanteric region and 29/41 of the femoral neck. Grade L was absent in the anterior and posterior pelvis.

In the normal female subjects, grade H-d was present in 6 of the 54 images of the anterior pelvis and was absent in the posterior pelvis and femoral elements. Grade H was present in 33/54 of the anterior pelvis, 22/54 of the posterior pelvis, and 8/54 of the femoral elements. Grade M was present in 15/54 of the anterior pelvis, 32/54 of the posterior pelvis, and 46/54 of the femoral elements. Grade L was present 17/54 of the femoral neck only. There was significance in the incidence of grades H-d and H among the three regional groups in both genders ($p<0.02$); its incidence decreased in order the anterior pelvis, posterior pelvis, femoral elements.

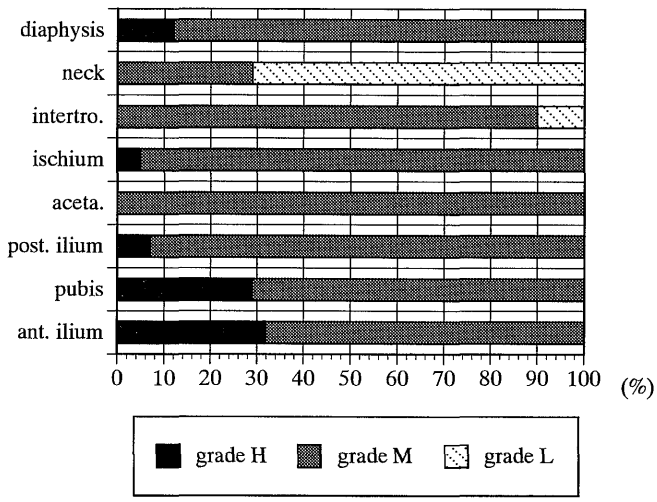

Figure 2. Loco-regional MSI patterns in male volunteers. The frequency (percentage of the total examinations) of grades H, M and L in each anatomic area is shown. Grade L was observed in the femoral neck and intertrochanteric region of the femur. Grade H-d was not observed in any anatomical area.
ant. = anterior, post. = posterior, aceta. = acetabulum, intertro. = intertrochanteric region of the femur, neck = femoral neck, diaphysis = proximal femoral diaphysis.

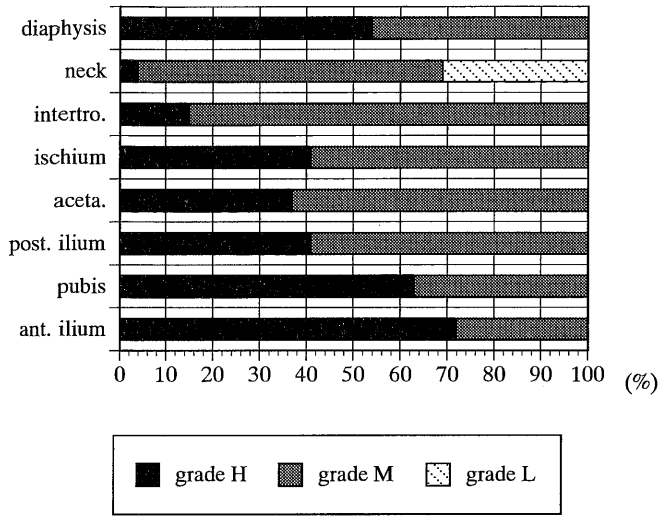

Figure 3. Loco-regional MSI patterns in female volunteers. The frequency (percentage of the total examinations) of grades H and M in each anatomic area is shown. Grade L was observed in the femoral neck. Grade H-d was observed in six subjects aged 35 years or younger in the anterior ilium and pubis, but they were classified together as grade H in this figure.
ant. = anterior, post. = posterior, aceta. = acetabulum, intertro. = intertrochanteric region of the femur, neck = femoral neck, diaphysis = proximal femoral diaphysis.

The proximal femoral diaphysis of the normal male and female subjects was grade H or grade M. The incidence of grade H in this region was higher than that in the posterior pelvis and lower than that in the anterior pelvis, although not significantly so.

The clinical and MR findings in the patients with AA and MDS are summarized in Table 1. Although the grade L pattern was not observed in the pelvis of the normal volunteers, grade L marrow was seen in the pelvis of the patients: among the 10 patients with AA, 7 showed grade L in the pelvis (Fig. 4); of the 19 patients with RA, 3 showed grade L pattern in the pelvis. The grade H marrow of the patients with RA was markedly heterogeneous in comparison with that of the normal subjects (Fig. 5). The signal intensity of the grade H-d and H marrow in the patients was much higher than that of the normal subjects. Grade H-d marrow was present in 6 of the 15 female volunteers aged 35 or younger and in 15 of 29 patients with MDS.

In the posterior pelvis, the grade H-d and H patterns were present significantly more often in the patients with MDS (25/29) than in the patients with AA (2 of the 10) ($p<0.05$). The grade H-d/H marrow in the posterior pelvis was also present significantly more often in the patients with RA (17/19) than in patients with AA (2/10) ($p<0.05$). The grade L marrow in the posterior pelvis was present in 7 of the 10 patients with AA, but in only 2 of the 29 patients with MDS ($p<0.05$).

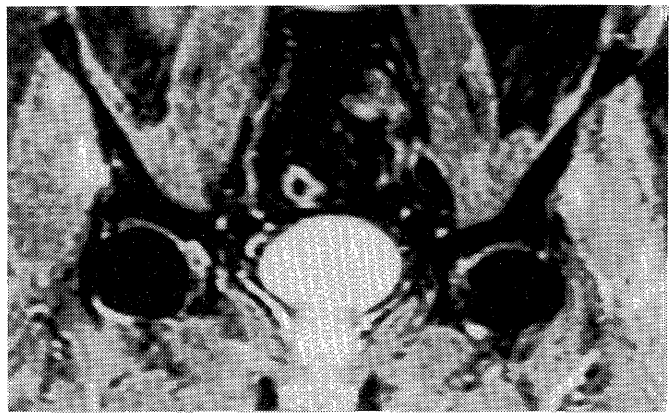

Fig. 4-A

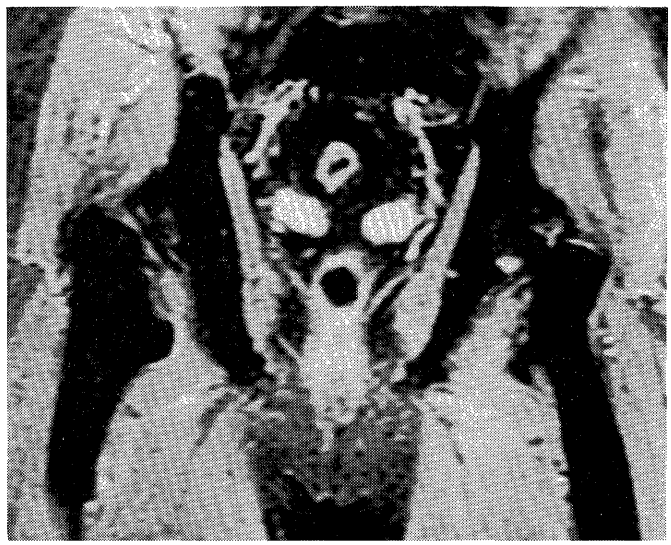

Fig. 4-B

Figure 4. STIR coronal images in a 58-year-old man with aplastic anemia (case 5). (A) The anterior pelvis (anterior ilium) and (B) the posterior pelvis (posterior ilium, ishium) show isointensity relative to adjacent fat (grade L) (not observed in normal volunteers). The femoral elements (intertrochanteric region of the femur) also show grade L.

In the anterior pelvis, the grade H-d and H patterns were present in 4 of the 10 AA patients and in 24 of the 29 MDS patients including 16 of the 19 RA patients; no significant difference existed among these groups in this parameter.

In the femoral elements, the grade H-d and H patterns were present in 6 of the 8 patients with severe MDS (RAEB, RAEB-T, and CMMoL) but in only 3 of the 19 patients with RA (Fig. 6) ($p<0.05$). Grade H-d and H patterns in the femoral elements was absent in all ten patients with AA.

In the proximal femoral diaphysis, the grade H-d and H pattern was present in 4 of the 10 AA patients and 24 of the 29 MDS patients (no significance).

One patient (case 15) with RA transformed from AA did not have grade H-d/H marrow in the pelvis.

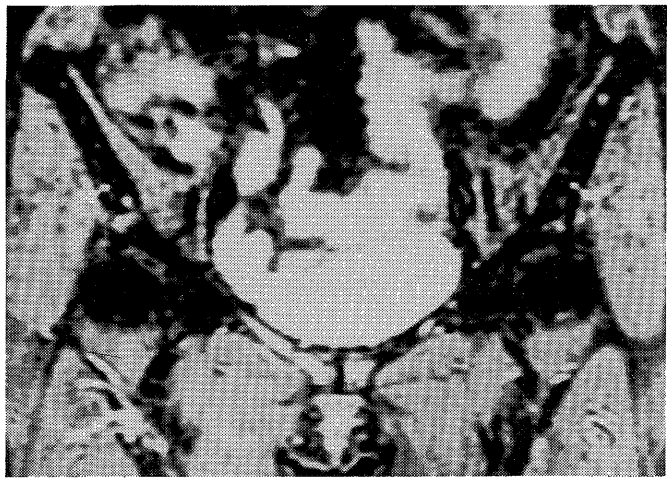

Fig. 5-A

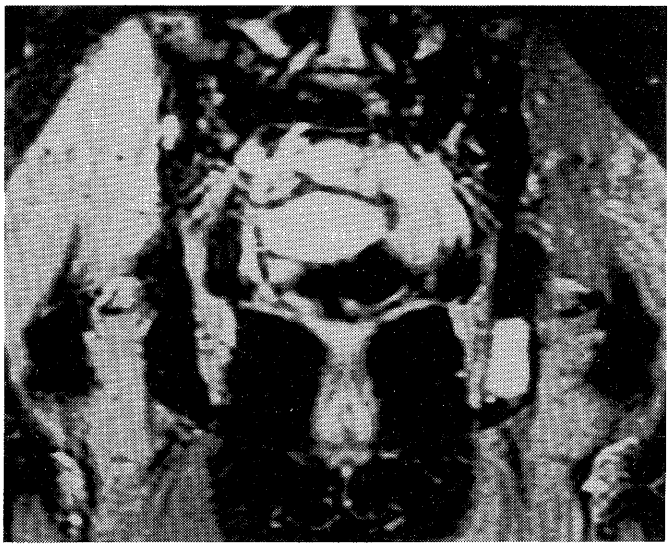

Fig. 5-B

Figure 5. STIR coronal images in a 55-year-old woman with refractory anemia (case 20). (A) The pubis shows grade H-d, and the right anterior ilium shows grade H. (B) The right posterior ilium and left ischium show grade H. The signal intensity of the grade H-d/H marrow is much higher than that of the adjacent muscle and is markedly hetrogeneous.

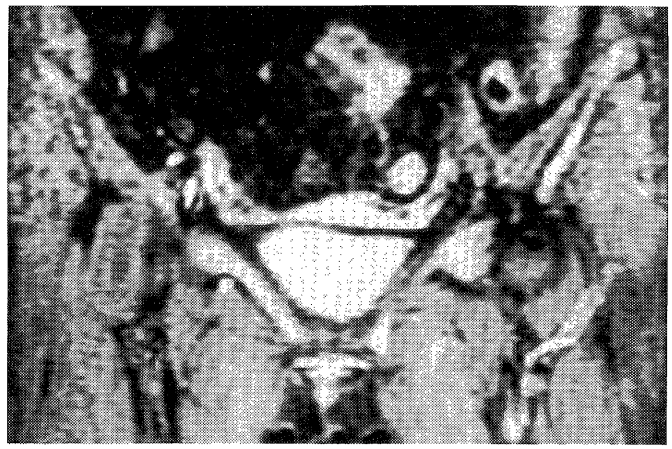

Fig. 6-A

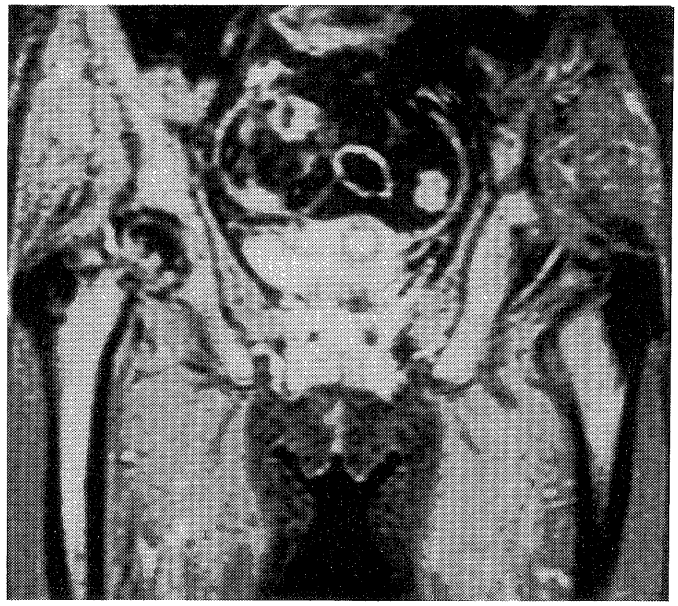

Fig. 6-B

Figure 6. STIR coronal images in a 67-year-old woman with refractory anemia with excess of blasts (case 36). (A) The anterior pelvis (left anterior ilium, right pubis), and (B) the posterior pelvis (right posterior ilium, right acetabulum, bilateral ischium), femoral elements (bilateral intertrochanteric region of the femur), and right proximal femoral diaphysis show grade H-d.

Discussion

The conversion of red to yellow marrow begins just before birth, and the marrow conversion progresses with age from the peripheral bones toward the central bones[19-26]. The adult pattern of red marrow distribution is attained by the age of 25 years, and red marrow generally exists in the skull, vertebrae, ribs, sternum, pelvis and proximal femora and humeri. Red marrow is composed of about 40% water, 40% fat, and 20% protein, while these proportions in yellow marrow are about 15%, 80%, and 5%, respectively[27]. The relative ratio of water/fat is regarded as the major factor affecting MSI, but the influence of the protein component on MSI has not been clarified[20]. Since water shows high signal intensity and fat shows low signal intensity on STIR, red marrow (which is abundant in water) shows high signal intensity and yellow marrow (abundant in fat) shows low or asignal intensity on STIR[17].

The MSI of the normal pelvis using standard spin echo sequences has been well described, but reports regarding MSI classification using STIR have not been published[3,4]. It is very interesting that in the present study, location-related differences were observed in the incidence of the grade H-d and H marrow, and that the pelvic bones could

be classified into the anterior and posterior pelvis according to its incidence. The MSI of the anterior pelvis was higher than that of the posterior pelvis on STIR images in this study, and this finding suggests that the bone marrow of the anterior pelvis is more abundant in water than is that of the posterior pelvis. In contrast, Dawson et al. reported that the MSI of the acetabulum and anterior ilium was higher than that of the posterior ilium on T1-weighted spin echo images, and their findings suggest that the bone marrow of the acetabulum and anterior ilium is more abundant in fat than is that of the posterior ilium[3]. Vogler mentioned that the MR appearance of bone marrow is dramatically influenced by the pulse sequence used[20]. Although the true cause of the disagreement between our data and Dawson's is not clear, this may be a reflection of the characteristics of the pulse sequences; STIR imaging delineates water in the bone marrow and T1-weighted spin echo imaging delineates fat in it[20].

AA and MDS are disorders of the stem cells and are characterized by pancytopenia[18,28]. The basic pathophysiologies of AA and MDS differ in that in AA, the marrow is unable to produce sufficient cells due to the reduction in the number of stem cells, and in MDS, the clonal increase in the number of the sick stem cells or atypical myeloblasts results in ineffective hematopoiesis. Our data using STIR imaging indicate that the MSI of the posterior pelvis is helpful for the differential diagnosis between AA and MDS: in the posterior pelvis, 7 of the 10 (70%) patients with AA had grade L marrow ; in contrast, grade L marrow was absent in 27 of the 29 (93%) patients with MDS. Grade H-d/H marrow of the posterior pelvis was present in 25 of the 29 (86%) MDS patients and in only 2 of the 10 (20%) AA patients. These observations strongly suggest that the MSI reflects the histologic features of AA and MDS; marrow in AA is hypocellular and that in MDS is hypercellular. Although two patients with AA had grade H marrow, these patients had been treated at the time of the MR examination. This finding is considered to be a reflection of treatment effect.

In the femoral elements, 6 of the 8 patients with severe MDS (RAEB, RAEB-T, and CMMoL) had grade H-d/H marrow. In contrast, only 3 of the 19 patients with RA and none of the 10 AA patients had grade H-d and H marrow in these regions. The presence of grade H-d and H patterns in the femoral elements suggests the diagnosis of severe MDS, but the absence of those grades cannnot differentiate AA from MDS. Our results are equivalent to those already published : it is difficult to diagnose MDS types accurately on the basis of MRI pattern[29]. The combination of the MSI of the posterior pelvis and that of the femur appears to be useful not only for the differentiation between AA and MDS but also for the diagnosis of severe MDS.

MDS patients usually have more hypercellular marrow with an increase in the numbers of both normal hematopoietic cells and atypical myeloblasts than do normal subjects. MDS with hypocellular marrow has recently been reported in the English-language literature[1,30,31].Three of the MDS patients in the present study (cases 15, 18, and 32) could not be diagnosed as having MDS according to the STIR findings; they did not show grade H-d/H marrow in the posterior pelvis and femoral elements. The absence of H-d/H marrow in the posterior pelvis may suggest that the marrow of the posterior pelvis is hypocellular. One MDS patient (case 15) suffered from RA that was tranformed from AA. The other two MDS patients (cases 18 and 32) might have had hypocellular marrow in the posterior pelvis; their biopsy specimens were obtained from the sternum, not the posterior pelvis. These paradoxical MR findings may be a reflection of the criteria of the French-American-British category: MDS was classified on the basis of the percentage of the atypical myeloblasts in the bone marrow irregardless of the total bone marrow cellularity; MR imaging delineates the total bone marrow cellularity, of both the atypical myeloblasts and normal hematopoietic cells[29].

In conclusion, grade H-d and H marrow of the posterior pelvis was present in 25 of 29 patients with MDS. In contrast, grade H-d and H marrow in this region was absent in 8 of 10 patients with AA. Since each disease clinically results in pancytopenia, these findings could be very helpful in differentiating between AA and MDS. Although 2 of the 10 patients with AA had grade H marrow in the posterior pelvis, this is probably a reflection of the increased cellularity after treatment. The MSI pattern in the posterior pelvis appears to be important in differentiating patients with AA from those with MDS.

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