

·

1

1,2

3

4

:

: 25

E. coli

3, 5, 1, 2, T1

4

T1

T2

:

3 - 5

가

T1

T2

· 3

3 - 5

T1

(3 75%; 5

60%)

가 1

T1

T2

가

가(3

17%; 5

40%; 1

46%; 2

56%; 4

60%)

(3

48%, 4

40%)

T2

가

T1

가

3

5

가

· 2

4

가

4

가

:

T1

T2

,

T1

가

T1

T2

가 가

(1, 2).

가

가

(saucerization)

1

2

3

4

1997

(02-1997-183)

1999 7 1

1999 9 8

:
 (3 25 , 5 5 , 1
 15 , 2 10 , 4 5)
 , , ,
 가
 (40 mg)
 E. coli 40mg 5 5 25
 2.3 - 4.5 (10^6 Colony Forming Unit(CFU)
 3.8×10^5 CFU 2-3kg 25
 Ketamine hydrochloride (Ketalar; Yuhan Cooperation , Seoul,
 Korea) 10mg/kg xylazine hydrochloride (Rom-pun; Bayer
 Korea, Seoul, Korea) 50mg/kg
 (metaphysis)
 (tibial tuberosity)
 (medial condyle) 18G Illinois needle(Manan,
 Illinois, U.S.A.) 5 (-; n=0, \pm ; n=1, +; n=2,3,
 ++; n=4, +++; n=5)
 가
 stylet
 Illinois needle
 (control group)
 3 (n=25), 5 (n=5), 1 (n=15), 2
 (n=10), 4 (n=5)
 1.5T (Magnetom Vision, Siemens, Erlangen,
 Germany) (surface coil)
 T1 (TR/TE = 500ms/15ms)
 T2 (TR/TE = 4000ms/96 ms)
 T1
 gadopentetate dimeglumine(Magnevist, Schering, Germany)
 0.2ml/kg . Matrix 256 \times 160,
 (field of view) 8.5 \times 8.5cm, 3mm ,
 가 25 3 , 5
 , 1 , 2 , 4 5
 thiopental sodium (Pentothal; Choong Wae
 Pharmacy, Seoul, Korea) 25
 10% 48 3 4%
 (decalcification)
 Nikon
 FM 2 camera 55mm macrolens, Kodak Ektachrome (Table 1, 2)
 daylight film 3 (n=25) (Fig. 1)
 Hematoxylin-eosin 6 μ m 가
 0.3 -1.5cm (0.9cm) T1
 T2

17 (68%) 가 가 T1
T2
(16/17,
94%) T1 (n=5)
가 (13/17, 76%). 25 12 (3/5)

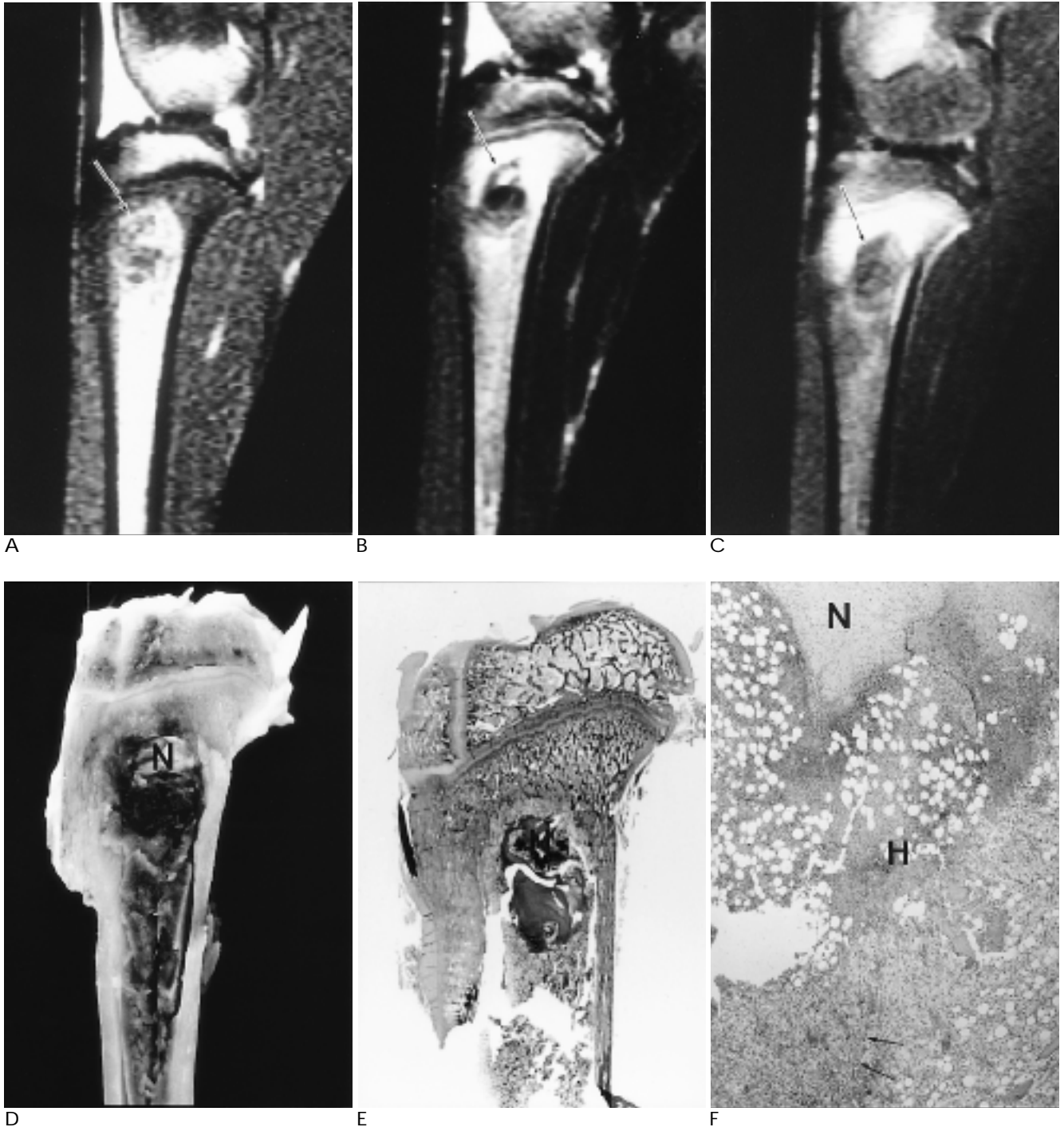


Fig. 1. Three days after pathogen inoculation. Sagittal T1-(A), T2-(B) and gadolinium enhanced T1-weighted(C) MR images show abscess of tibia. Wall is partly visualized, which shows slightly high SI on T1WI and low SI on T2WI and slightly enhanced. Gross photograph(D) reveals central necrosis(N) and hemorrhage. Corresponding histologic section(E, H&E stain; original magnification, $\times 1$) and magnified view(F, original magnification, $\times 40$) show necrosis(N) and hemorrhage(H) with surrounding granulation tissue composed of proliferating fibroblasts and vessels(arrows).

3 3 가 가

3

(3/5) 2 가 가

1 (congestion)

T1 T2

T1

(76%)가

5 (n=5) (Fig. 2)

(0.4 -1.5cm, 0.9cm) 3 1 (n=15) (Fig. 3)

5 (100%) T1 T2

T1

3 (9/12, 75%) (3/5,

60%) T1 T2

가 3 (2/12, 17%)

가(2/5, 40%) (n=5) 5

가

2 , 1 , 2

(foreign body) 5

3

가 2

T1

13

T2 (11/13, 85%)

6 T1 5

T1

(9/12, 75%) (3/5, 60%)

(7/13, 54%) , T1

(2/5, 40%) 가 3 (2/12, 17%) 5

(n=5) 5 가(6/13, 46%)

가

Table 1. Changes of MR Imaging Findings of Marrow Lesions after Pathogen Inoculation

Findings	Number of Cases				
	3 days (n= 25)	5 days (n= 5)	1 week (n= 15)	2 weeks (n= 10)	4 weeks (n= 5)
Center*					
L/L/-	25	5	15	10	5
Wall*					
H/H/+	7	1	5	2	2
H/L/+	6	2	2	2	0
L/H/+	3	2	6	5	3
L/L/ -	1	0	0	0	0
No wall	8	0	2	1	0
Periphery*					
L/H/+	12	0	0	0	2
Iso	13	5	15	10	3

* Each cell is presented according to the order of SI on T1WI / SI on T2WI / positive or negative Gd-enhancement (SI: signal intensity, T1WI: T1-weighted image, T2WI: T2-weighted image). L: low SI, H: high SI, + : positive Gd-enhancement, - : negative Gd-enhancement Iso: iso SI with normal marrow without Gd-enhancement

Table 2. Changes of Pathologic Findings of Marrow Lesions after Pathogen Inoculation

	Grade of Pathologic Findings				
	3 days (n= 5)	5 days (n= 5)	1 week (n= 5)	2 weeks (n= 5)	4 weeks (n= 5)
Center*					
Hemorrhage	++	±	-	-	-
Necrosis	+	+++	+++	+++	+++
Dead bone	±	+	+	±	-
New bone	-	-	±	-	-
Wall#					
Fibroblast	+++	++	+	±	±
Neutrophil	++	+++	+	±	±
Lymphoplasm cell	-	±	+	++	+++
Periphery*					
Granulation tissue	+	-	-	-	+
Congestion	±	-	-	-	-

* -: n= 0, ±: n= 1, + : n= 2,3, ++ : n= 4, +++ : n= 5

-: absence, ± : minimal, + : mild, ++ : moderate, +++ : marked

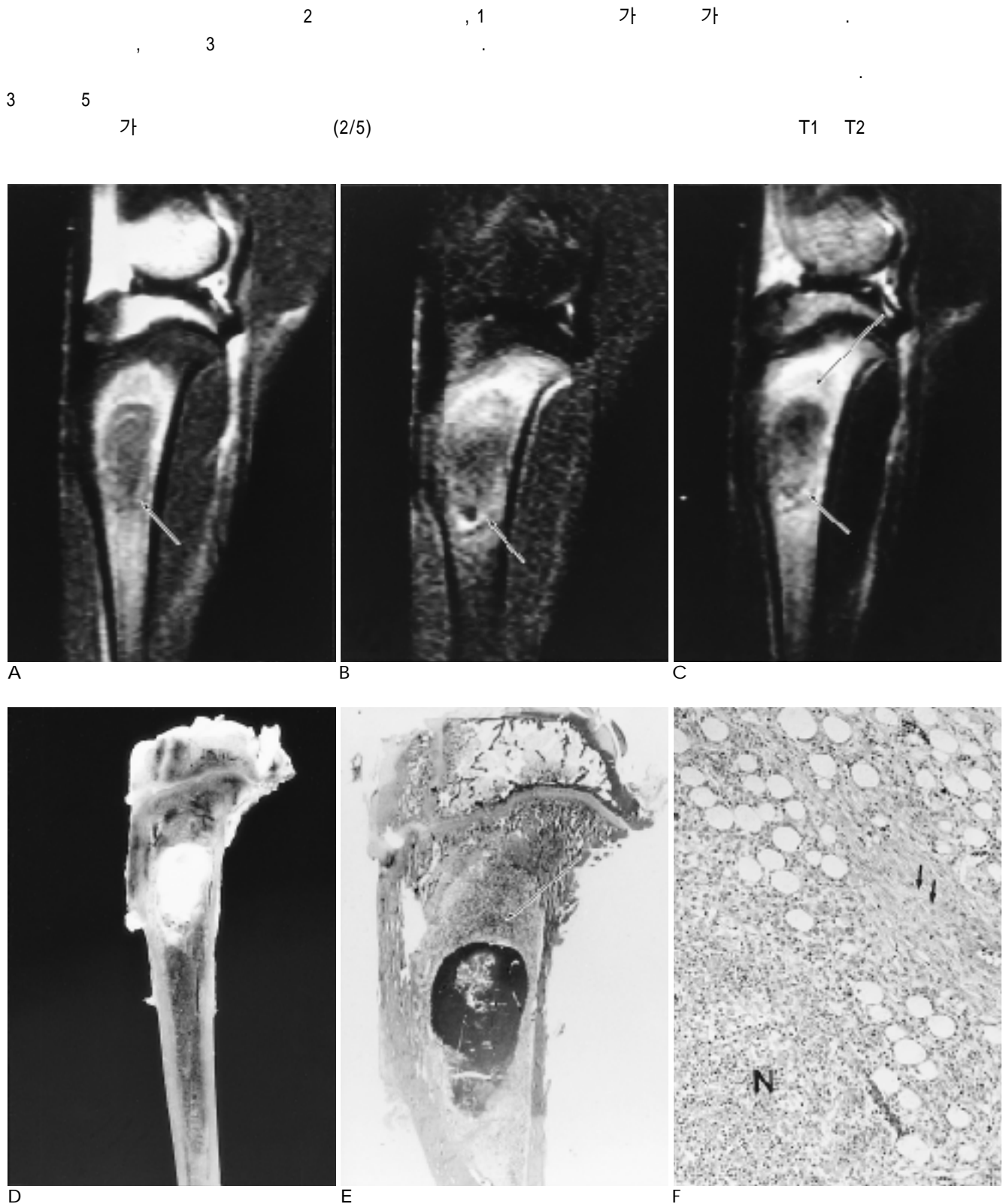


Fig. 2. Five days after pathogen inoculation. Sagittal T1-(A), T2-(B) and gadolinium enhanced T1-weighted(C) MR images show abscess of tibia. Abscess wall(arrow) shows high SI on T1 and T2WI. Ring enhancement with thick upper portion(long arrow) surrounds the lesion. Gross photograph(D) reveals ovoid central necrosis. Corresponding histologic section(E, H&E stain; original magnification, $\times 1$) shows thick granulation tissue(long arrow) at the upper portion of abscess wall. Magnified view(F, original magnification, $\times 100$) shows central necrosis(N) containing cell debris and neutrophils. The wall reveals less cellular granulation tissue composed of a few fibroblasts(arrows).

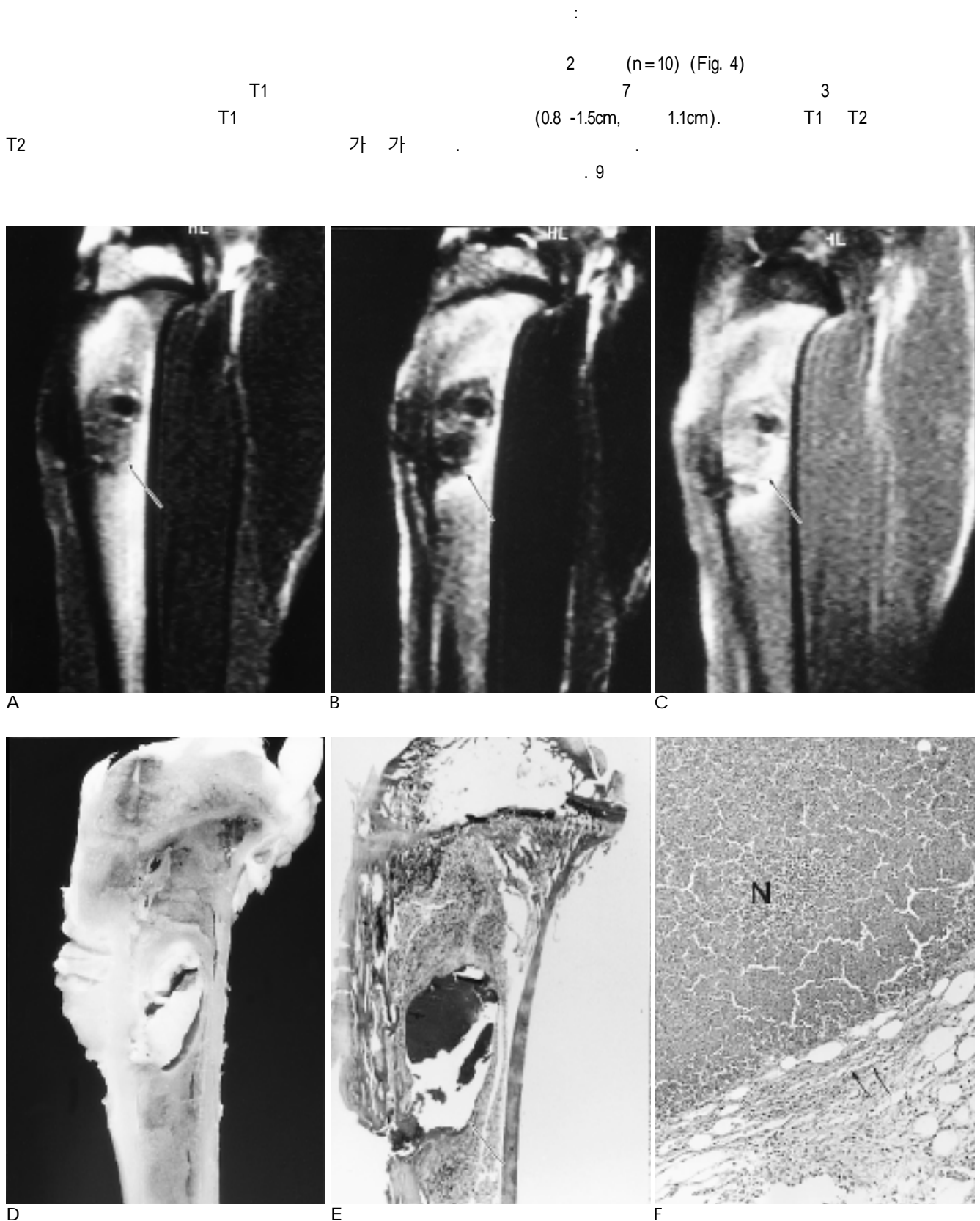


Fig. 3. One week after pathogen inoculation. Sagittal T1-(A), T2-(B) and gadolinium enhanced T1-weighted(C) MR images show abscess of tibia. Abscess wall shows low SI(arrow) on T1WI and high SI(arrow) on T2WI. Ring enhancement(arrow) surrounds the lesion. Gross photograph(D) reveals well-defined central necrosis. Corresponding histologic section(E, H&E stain; original magnification, $\times 1$) shows granulation tissue(arrow) surrounding central necrosis. Magnified view(F, original magnification, $\times 100$) shows central necrosis(N) containing cell debris and neutrophils. The wall reveals less cellular granulation tissue composed of a few fibroblasts(arrows).



Fig. 4. Two weeks after pathogen inoculation. Sagittal T1-(A), T2-(B) and gadolinium enhanced T1-weighted(C) MR images show abscess of tibia. Abscess wall shows low SI(arrow) on T1WI, high SI(arrow) on T2WI and ring enhancement(arrow) after Gd-infusion. Gross photograph(D) demonstrates abscess. Corresponding histologic section(E, H&E stain; original magnification, $\times 1$) shows layer of inflammatory cells(arrow) surrounded by granulation tissue. Magnified view(f, original magnification, $\times 200$) shows inner layer (I) of plasma cells and macrophages and outer granulation tissue layer(O).

phage)



Fig. 5. Four weeks after pathogen inoculation. Sagittal T1-(A), T2-(B) and gadolinium enhanced T1-weighted(C) MR images show abscess of tibia. Abscess wall(arrow) shows high SI on both T1 & T2WI and diffuse enhancement after Gd-infusion. Gross photograph(D) demonstrates abscess. Corresponding histologic section(E, H&E stain; original magnification, $\times 1$) shows localized organized abscess(arrow) with central abscess(A). Magnified view(F, original magnification, $\times 100$) shows inner layer(I) of foreign body granulomas and chronic inflammatory cells and outer layer(O) of granulation tissue. Note that granulation tissue shows more organized features than that of Fig. 4(F).

2
T1 , T2
T1
T2
가 3
가
1
T2
(Fig. 6 A-C) T1
2
가 T1
, T2
(n=5)
T2
2
가 가 4
(organized)
T2
(Fig. 6D-F).
가
가

Table 3. Changes of MR Imaging Finding of Marrow Lesions in Control Group

Findings	Number of Cases				
	3 days (n= 25)	5 days (n= 5)	1 week (n= 15)	2 weeks (n= 10)	4 weeks (n= 5)
Center*					
L/L/ -	25	5	15	8	2
No lesion	0	0	0	2	3
Wall*					
H/H/+	7	1	3	2	2
H/L/+	1	0	0	0	0
L/H/+	3	2	0	0	0
L/H/-	1	0	0	0	0
L/L/+	1	0	2	2	1
L/L/-	2	0	2	1	0
No wall	10	2	8	5	2
Periphery*					
L/H/+	9	0	0	0	0
H/H/+	1	0	0	0	0
L/L/+	1	0	0	0	0
Iso	14	5	15	10	5

*Each cell is presented according to the order of SI on T1WI / SI on T2WI / positive or negative Gd-enhancement (SI: signal intensity, T1WI: T1-weighted image, T2WI: T2-weighted image).

L: low SI, H: high SI, + : positive Gd-enhancement, - : negative Gd-enhancement, Iso: iso SI with normal marrow without Gd-enhancement

T2
T1
T2
(Table 3,4)
(puncture) 3 (n=25) (Fig. 7)
가 0.3- 1.5cm (0.7cm)
T1 T2
15
가
T1 T2
가 7 가
5
가
가
5 (n=5)
3
(0.3- 1.4cm, 0.7cm), T1 T2
3
(n=5) 3
1
1

Table 4. Changes of Pathologic findings of Marrow Lesions in Control Group

	Grade of Pathologic Findings				
	3 days (n= 5)	5 days (n= 5)	1 week (n= 5)	2 weeks (n= 5)	4 weeks (n= 5)
Center*					
Hemorrhage	+	+	±	-	-
Necrosis	-	+	±	-	-
Dead bone	±	+	++	+	-
New bone	-	±	++	+	-
Granulation tissue	+	-	-	±	-
Fatty marrow	-	-	-	±	+++
Wall					
Granulation tissue*	+	+	+	+	-
Neutrophil*	-	±	-	-	-
Lymphoplasmal cell*	-	±	-	-	-
Periphery*					
Congestion	±	-	-	-	-

* -: n= 0, ± : n= 1, + : n= 2,3, ++ : n= 4, +++ : n= 5

※ -: absence, ± : minimal, + : mild, ++ : moderate, +++ : marked

※ -: absence, + : presence

가

1 (n=15)

1.2cm, 0.5cm), T1 T2

5 (0.3-

7

(n=5) 4

1

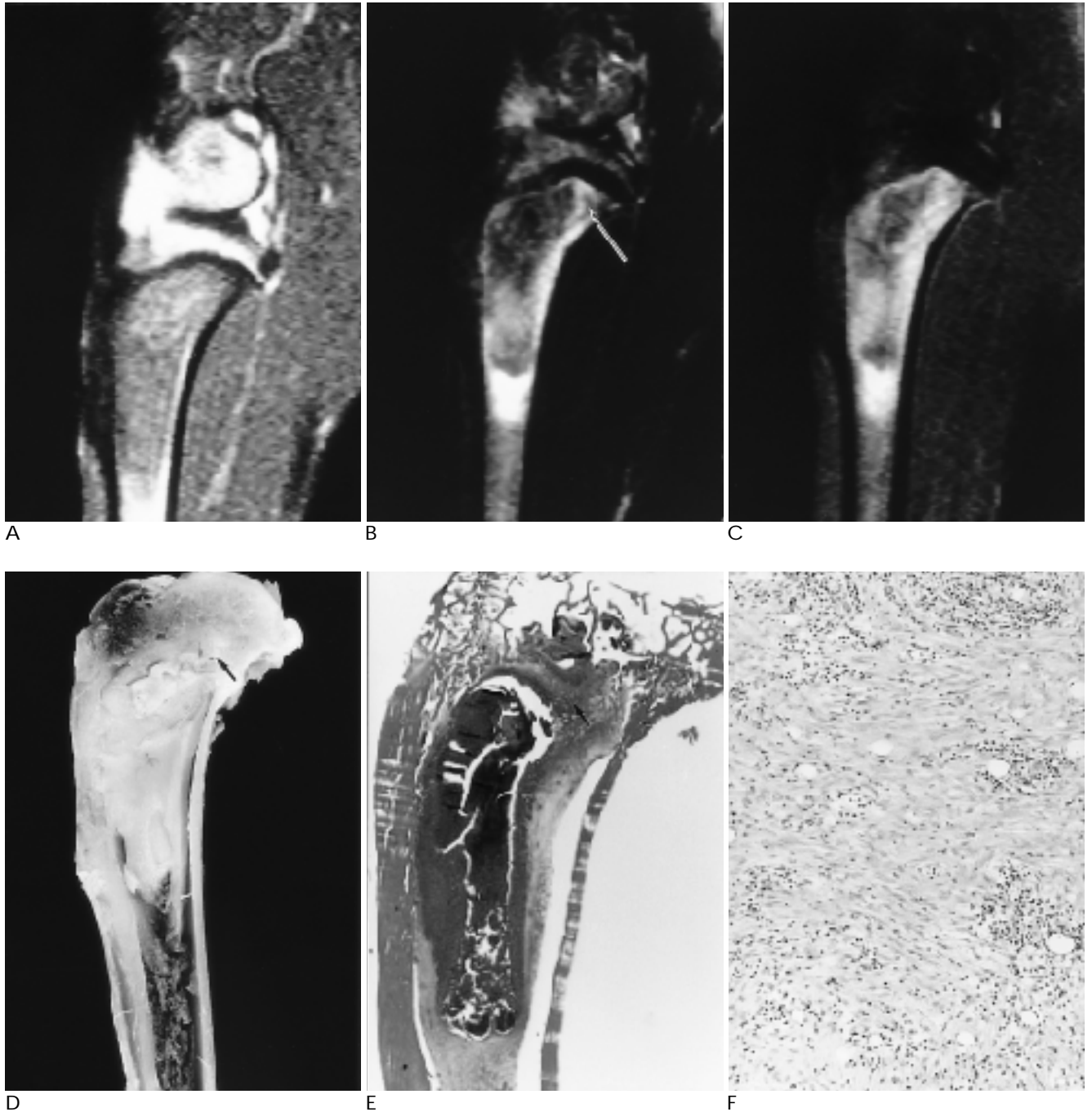
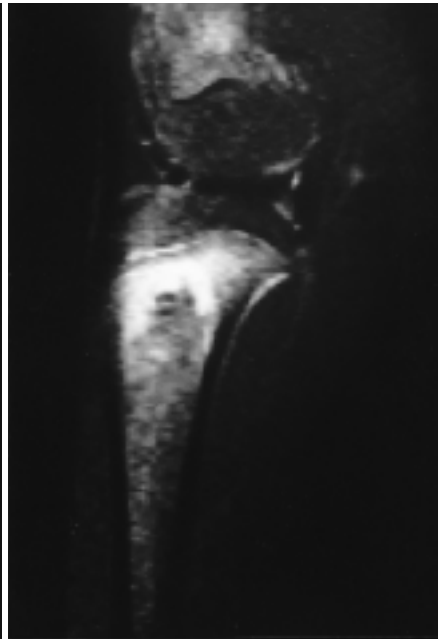


Fig. 6. Localized fibrosis of the abscess wall after 4 weeks of pathogen inoculation. Sagittal T1-(A), T2-(B) and gadolinium enhanced T1-weighted(C) MR images show abscess of tibia. Postero-superior aspect of the wall shows low SI(arrow) on T2WI, but iso SI with the other portion of the wall on T1WI and Gd-enhanced image. Corresponding gross photograph(D) and histologic sections(E, F, H&E stain; original magnification, $\times 1$ & $\times 100$) show localized advanced fibrosis(arrow in d & e).

2 (n=10) 7 가 3
(0.2-0.6cm, 0.4cm).
가 1 2 (n=5)
4 1
가



A



B



C



D



E

Fig. 7. Medullary cavity 3 days after puncture with Illinois needle (control side of the same rabbit shown in Fig. 1).

Sagittal T1-(A), T2-(B) and gadolinium enhanced T1-weighted(C) MR images show small lesion of tibia. Center shows dark signal intensity on both T1 and T2WI without enhancement and wall is visualized. Gross photograph(D) reveals central dead bone

and hemorrhage. Corresponding histologic section(E, H&E stain; original magnification, $\times 40$) shows dead bone(D) and hemorrhage(H) with surrounding granulation tissue(arrow).

가 : 가 가 가

가

4 (n=5) (Fig. 8)

(0 - 0.2cm, 0.1cm) 가

(n=5) (natural history) T2

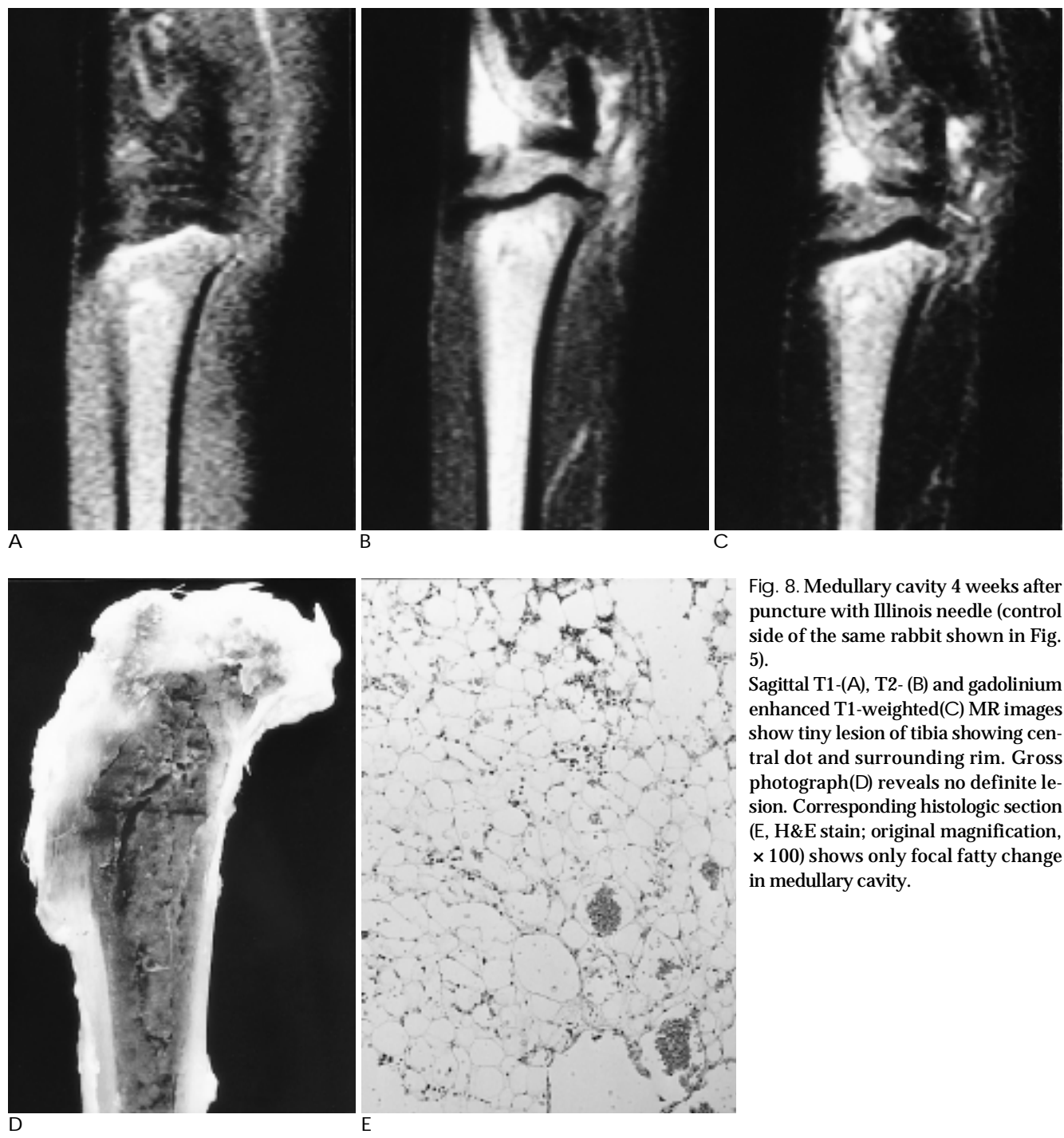


Fig. 8. Medullary cavity 4 weeks after puncture with Illinois needle (control side of the same rabbit shown in Fig. 5). Sagittal T1-(A), T2- (B) and gadolinium enhanced T1-weighted(C) MR images show tiny lesion of tibia showing central dot and surrounding rim. Gross photograph(D) reveals no definite lesion. Corresponding histologic section (E, H&E stain; original magnification, $\times 100$) shows only focal fatty change in medullary cavity.

(7-9) . (axial)
가
(17/25, 76%) ,
(10) (1)
, 가
(11). 가 . Capitanio
(11). 가 (11) (edema)
3
sodium 10-12 (7). Crane
sodium m- X (xeroradi-
morphuate가 (12, 13). ograph)
Norden (12, 13) , (involucrum)
5
E. coli가 , 10
가 , 15 20 ,
(6, 14) 가
가 (periosteal new bone formation)
가 E. coli (8).
3 가
,
,
가 (9).
E. coli 가
E. coli 가
가
가 E. coli 5
, 가
가
75% (14) (15, 16).
가 가 가 (ac-
가 , tive infection foci) T1
797

- (8).
- 가 20
20
가
- 가 . 가 3
가
- 가 가
- 4
- 1
sodium morrhuate Crane
- 가 4
- T1 T2 ,
- T1 가 T1
T1 T2
1. Emslie KR, Nade S. Pathogenesis and treatment of acute hematogenous osteomyelitis: evaluation of current views with reference to an animal model. *Rev Infect Dis* 1986;8:841-849
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Correlation between MR Imaging and Histopathologic Findings in Acute Osteomyelitis: Experimental Study in Rabbits¹

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Purpose : We compared the sequential characteristic MR findings with histopathologic findings in experimentally induced osteomyelitis of rabbits' tibiae.

Materials and Methods : We induced osteomyelitis in the left tibiae of 25 rabbits by direct inoculation of *E. coli*. Right tibiae of the same rabbits were directly punctured with sterile needle, which were used as control groups. Spin-echo sagittal T1- and T2-weighted images (T1WI & T2WI) and gadolinium-enhanced T1-weighted sagittal images of both tibiae were obtained at 3 days, 5 days, 1 week, 2 weeks, and 4 weeks following inoculation of pathogen. MR-pathologic correlation study was done with emphasis on changes of the morphology and the MR signal intensity (SI) of marrow abscess.

Results : Well-defined abscesses were seen on MR 3 - 5 days after pathogen inoculation and they all showed low SI on both T1 & T2WI and no enhancement. MR imaging of abscess wall, which became visible at 3 days as high SI on T1WI, gradually changed to low SI on T1WI and high SI on T2WI with diffuse enhancement according to the time sequence (17% after 3 days; 40% after 5 days; 46% after 1 week; 56% after 2 weeks; 60% after 4 weeks). The peripheral portion of the abscess, which was seen in some cases (48% after 3 days; 40% after 4 weeks), showed iso-intensity to muscle on T1WI and ill-defined high SI on T2WI with mild Gd-enhancement. Pathologically the abscesses and their walls were composed of cell debris and granulation tissue with infiltration of inflammatory cells. Fibroblasts and acute inflammatory cells in the abscess wall, which were most prominent at 3 and 5 days relatively, decreased gradually along with the development of abscess. Inner layer of the abscess wall was composed of chronic inflammatory cells, which appeared after 2 weeks of inoculation. The granulation tissue and inner chronic inflammatory cell layer became more organized feature after 4 weeks. The peripheral portion of the abscess revealed as granulation tissue. In the control group, necrosis or inflammatory cell infiltration was absent and the lesion decreased in size to remain only focal fatty change of bone marrow after 4 weeks.

Conclusion : Central abscess composed of cell debris showed low SI on both T1 & T2WI without enhancement. Granulation tissue of the abscess wall showed more organized feature forming inner layer of chronic inflammatory cells along with the progression of osteomyelitis. Abscess showed hyperintensity on T1WI in the early stage, but changed to hypointensity on T1WI, hyperintensity on T2WI in later stage.

Index words : Animals

Bones, infection

Bones, mR

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