

Occurrence of Marrow Edema in Early Stage Osteonecrosis of the Femoral Head (A Prospective Study with Repeated MR Imagings)

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= Abstract =

Thirty-six femoral heads with non-traumatic osteonecrosis(ON) at precollapse stage in 32 patients were studied with repeated magnetic resonance(MR) imagings at three-month intervals to reveal the occurrence of marrow edema of the proximal femur in early stage ON. Eighteen hips were randomly selected for the core decompression and the remaining 18 hips were treated conservatively. The criteria of marrow edema in this study were signal abnormalities of low signal intensity in T1-weighted image, and isointensity or hyperintensity in T2-weighted image which involved the femoral head beyond the necrotic zone, extending to the neck and trochanteric area.

Eight femoral heads demonstrated marrow edema at the initial MR imaging and seven out of eight were associated with pain for one to six weeks before the first MR study. Core decompression was performed on four out of those seven symptomatic femoral heads with marrow edema after the first MR imaging. The symptom was relieved promptly in three out of four core decompressed hips. The remaining one core decompressed case showed recurrent marrow edema on follow-up MR imagings. Out of 28 hips free of marrow edema at the initial MR study, 14 hips underwent core decompression after the first evaluation and the remaining 14 hips were treated conservatively. One out of 14 core-decompressed hips and three out of 14 nonoperated hips showed marrow edema in follow-up MR studies. Two cases experienced hip pain while two cases remained symptomless at the presence of marrow edema. Four femoral heads underwent core biopsy and three cases received total hip arthroplasty at the presence of marrow

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edema. In those four hips which underwent core decompression during the presence of marrow edema, intraosseous pressure(IOP) ranged from 36 to 60 (mean; 49) mmHg. In the remaining 14 core decompressed hips, the IOP ranged from 16 to 52 (mean; 37) mmHg. The histology of those four core biopsies and three resected femoral heads showed a collection of eosinophilic plasma-like fluid in the marrow space around the necrotic zone, a finding compatible with marrow edema.

This study suggests that marrow edema of the proximal femur may occur during the progression of the ON of the femoral head and is frequently associated with increased intraosseous pressure and pain. Core decompression can relieve marrow edema and associated pain promptly. But the effect is temporary, and core decompression does not prevent marrow edema permanently.

Key Words : Osteonecrosis, MR imaging, Marrow edema.

INTRODUCTION

Marrow edema of the proximal femur has been known to be related to two different diseases of the hip, transient osteoporosis of the hip which regresses spontaneously after several months and non-traumatic osteonecrosis(ON) of the femoral head which progresses to a state of collapse of the femoral head and subsequent degenerative arthritis of the hip^{1,3,4,7,10,11}. Magnetic resonance (MR) studies of transient osteoporosis of the hip revealed the involvement of marrow edema in that disease. Some authors consider marrow edema to be an early and possibly reversible phase of ON^{4,7,10}.

So far the etiology of marrow edema and its possible role in the pathogenesis of ON have been poorly understood.

The purpose of this study was to reveal the occurrence of marrow edema during the progression of early stage ON and its clinical implications as well as to evaluate the role of core decompression in the relief and prevention of marrow edema.

METHODS

Patients who were suspected of having ON of the femoral heads were studied with clinical evalu-

ation, plain roentgenography and MR imaging. A diagnosis of ON was made if the femoral head showed definite findings on plain radiographs and/or MR images⁹ with or without histologic evidence of ON. The hips were staged using the classification by Steinberg⁸. The cases of early-stage ON were randomized to a treatment protocol of either core decompression or conservative treatment. Intraosseous pressure(IOP) was also measured in the core decompressed femoral heads. All cases were followed up by the clinical and roentgenographic evaluations and repeated MR imagings at three-month intervals. The occurrence of marrow edema was estimated from the serial MR images. The clinical feature, alteration of IOP and histologic findings during the attack of marrow edema were analyzed. The role of core decompression in the relief and prevention of marrow edema was evaluated. The study was stopped when the plain radiographs demonstrated the collapse of the femoral head.

Clinical evaluation was done using the Harris Hip Score. Plain radiographs included standard anteroposterior and frog-leg lateral views. MR imagings were performed using either of two 1.0 Tesal superconducting units. T1-weighted spin-echo images(echo time [TE], 15-20 ms; repetition time [TR], 150-200 msec) and T2-weighted

images(echo time[TE], 80-90 msec; repetition time[TR], 2000-2500 msec) were obtained on coronal, sagittal and axial planes. The section thickness was 5-10 mm with no gap. Images were reconstructed using a 128x256 or 256x256 matrix. The excitation number ranged from one to four. The findings from MR images, to be considered positive for marrow edema, were signal abnormalities of low signal intensity in T1-weighted images, and isointensity or hyperintensity on T2-weighted images which involved the femoral head and neck beyond the necrotic zone, extending to the trochanteric area. IOP was measured from the trochanteric area on hips which underwent core decompression, using the method described by Ficat²⁾ and Hungerford³⁾. Core biopsy was performed with a 9.5 mm trephine, under the guidance of fluoroscopy. A cortical window was made just below the trochanteric ridge and the coring advanced into the anterosuperior portion of the femoral head until the tip reached within 5mm of the subchondral plate. The proximal portion of the decompression tract was filled with intact cancellous bone from the trochanteric area. Biopsy specimens were fixed in 10% neutral buffered formalin and were decalcified in a solution of formic acid and sodium citrate. Four micrometer thick sections were cut and stained with hematoxylin and eosin. Postoperative management consisted of protected weight-bearing for six weeks, followed by a gradual increase in weight-bearing for another six weeks. Conservative treatment consisted of non-weight bearing and intermittent use of analgesics until the pain subsided. Total hip arthroplasty (THA) was performed in cases of collapsed femoral heads with intractable pain in spite of conservative management.

RESULTS

A total of 36 femoral heads with precollapse ON in 32 consecutive patients(30 male and two

female, aged 18-68 years) was followed in this prospective study protocol. The associated conditions of factors in ON included alcohol abuse in 27 patients and a history of high-dose steroids in three patients(two nephrotic syndromes and one hypophysectomy state due to craniopharyngioma). In the remaining two patients no risk factor could be identified. All 36 hips were followed up either for a period of 24 to 42 months(mean, 31 months) or until plain radiographs demonstrated the collapse of the femoral head(range, 3-36 months; mean, 9.8 months). Fourteen hips were symptomatic at the time of the first presentation. Eighteen hips(ten symptomatic and eight asymptomatic hips) were randomly selected for the core decompression with IOP measurement and the remaining 18 hips were treated conservatively. At the minimum follow-up of 24 months, failure by radiographic evidence of collapse of the femoral head was: 14/18(78%) in the core-decompressed group and 15/18(83%) in the conservatively treated group. Thirteen hips(72%) in the cored group and 13 hips(72%) in the nonoperated group failed as defined by conversion to THA. Twelve hips(12/36, 33%) in 11 patients with precollapse ON showed a characteristic pattern of marrow edema at the initial MR imaging(eight hips) or follow-up studies(four hips). Ten(83%) of the 12 hips which showed marrow edema were associated with an occurrence or aggravation of pain. Eight femoral heads demonstrated diffuse marrow edema at the initial MR imaging and seven out of eight were associated with pain for one to six weeks before the first MR study. Core decompression was performed on four out of those seven symptomatic femoral heads with marrow edema at first study. The symptom was relieved in three out of four core decompressed hips. Pain persisted in one core decompressed hip and in two nonoperated hip. The second MR study demonstrated a complete disappearance of marrow edema in six hips(Fig. 1). But two cases(one core decompressed

Fig. 1A-1E. Case 1. A 55-year-old male with a history of alcohol abuse. He suffered right hip pain for six weeks. Plain roentgenograms revealed Steinberg stage III ON on right hip and stage II ON on left hip. (A) MR imaging revealed Mitchell class A lesion on both femoral heads. Diffuse signal abnormalities compatible with marrow edema were observed on right hip. (A)T1-weighted spine-echo image. (B)T2-weighted spine-echo image. (C)The second MR imaging revealed disappearance of marrow edema. Nine months later from the initial study the patient experienced a newly developed pain on left hip (D) The fourth MR imaging showed diffuse marrow edema on left hip. The patient was treated with THA on both hips. (E) Histology of left femoral head confirmed ON and marrow space was filled with eosinophilic fibrinoid material which was a finding compatible with marrow edema(Stain, hematoxylin and eosin ; oritinal magnification, x1).

and one nonoperated) out of three in which pain had not been relieved revealed persistent edema in the second MR study. The initial MR study showed that 28 femoral heads of precollapse ON were free of marrow edema.

Core decompression was performed on 14 out of

those 28 hips after the initial study and the remaining 14 hips were treated conservatively. One out of 14 core-decompressed hips and three out of 14 nonoperated hips showed marrow edema in follow-up MR studies at five to 12 months from the first study(Fig. 2). Those four cases had minimal

Fig. 2A-2D. Case 2. A 27-year-old male who had been treated with high dose of prednisolon due to nephrotic syndrom. He was referred due to left hip pain. Right hip was asymptomatic. Plain radiographs revealed Steinberg stage IV ON on left hip. (A) MR imaging showed Mitchell class A On on right hip and class D lesion with joint effusion on left side. THA was performed on left hip and right hip underwent core biopsy. Histologic findings were compatible with ON on both specimens. (B) Second MR imaging at three months after core decompression. Six months after the operation, he experienced sudden pain on right hip. There was no detectable change on plain radiogram since previous study. (C) Third MR imaging which was performed three days after the onset of pain revealed diffuse signal intensity compatible with marrow edema. He was treated with limited weight-bearing and anti-inflammatory medication, but the pain was not improved. Redrilling of right femoral head was performed eight weeks after the onset of pain. The pain was relieved promptly after redrilling. But the pain recurred

again four weeks after redrilling. At nine months from the initial study right femoral head collapsed and THA was performed. (D) Marrow space was filled with eosiniphilic fibrinoid material on histologic evaluation (Stain, hematoxylin and eosin original magnification, X1).

Table 1. The Profile of 11 Patients of Early-Stage ON of the Femoral Head with Marrow Edema on MR Imagings

Case No.	1	2	3	4	5	6	7	8	9	10	11
Age/Sex	M55	M27	M49	M38	M68	M56	M39	M68	M42	M49	M39
Affected side	R	L	R	L	R	L	L	R	R	L	L
Risk Factor	Al		St	Al	Id	Al	Al	Al	Al	Al	Al
Initial											
Steinberg stage	III	II	I	II	II	II	I	II	I	II	II
Bone scan	+	-	-	+	+	+	-	+	+	+	+
IOP(mmHg)	-	-	45	28	58	36	-	60	-	42	-
Hip pain & duration	+	-	-	+	+	+	-	+	+	+	+
	6Wk			2Wk	1Wk	3Wk		4Wk	-	2Wk	4Wk
Treatment	NO	NO	CD	CD	CD	CD	NO	CD	NO	CD	NO
Pain relief after treatment	+	UC	UC	+	+	+	UC	-	UC	+	+
Marrow edema											
Time of edema	0Mo	6Mo	6 & 9Mo	3Mo	0Mo	0Mo	12Mo	0Mo	0Mo	0Mo	0Mo
Pain with edema	+	+	+	+	+	+	-	+	-	+	-
Progression of collapse & time	+	+	+	+	-	+	-	+	+	+	+
Duration of FU	3Mo	6Mo	9Mo	3Mo		36Mo		6Mo	9Mo	6Mo	6Mo
					24Mo		33Mo				3Mo
Final											
Steinberg stage	IV	IV	IV	IV	II	IV	II	IV	IV	IV	IV
Treatment	THA	THA	THA	THA	-	THA	-	THA	THA	THA	THA
Biopsy specimen during edema	-	FH	FH	FH	CB	CB	-	CB	-	CB	-

Note: No.=number, R=right, L=left, Al=alcohol, Id=idiopathic, St=steroid, IOP=intraosseous pressure, Wk=weeks, Mo=months, NO=nonoperativetreatment, CD=core decompression, UC=uncheckable, FU=follow up, THA=total hip arthroplasty, FH=femoral head, CB=core biopsy.

Case 1: marrow edema occurred on both hip.

Case 2 and 3: two cases in which marrow edema occurred after core-decompression. Case 2 underwent redrilling due to recurrent pain associated with marrow edema 6 months after core decompression and THA was performed at 9 months due to collapse with severe pain and marrow edema.

Case 1 left hip and cases 2, 3, 4, 5, 7 and 9: seven cases in which biopsy specimens were obtained during the attack of marrow edema.

or no symptom at first presentation(Table 1). Two cases experienced hip pain while two cases remained symptomless at the presence of marrow edema. Four femoral heads underwent core biopsy and three cases received total hip arthroplasty during the attack of marrow edema. In those four core decompressed hips during the presence of marrow edema, the IOP ranged from 36 to 60 (mean; 49) mmHg. In the remaining 14 core decompressed hips, the IOP ranged from 16 to 52 (mean; 37) mmHg. The histology of those four core biopsies and three resected femoral heads showed a collection of eosinophilic plasma-like fluid in the mar-

row space around the necrotic zone, a finding compatible with marrow edema.

DISCUSSION

Localized edema due to venous or lymphatic obstruction or to increased vascular permeability may be associated with various diseases such as infection, tumor and trauma which induce inflammatory processes in the interstitial space. Ischemic infarct of various organs has been known to be associated with a surrounding edema during the acute or subacute stage of the disease process.

During acute cerebral infarct, the surrounding edema with increased intracranial pressure is observed for several days after the ischemic attack, and is resolved later. Marrow edema is related to many different diseases of the bone such as osteomyelitis, bone tumor, osteoarthritis and fracture. Characteristic findings are shown on MR images and have been known to be related to two different diseases of the hip, transient osteoporosis of the hip which regresses spontaneously after several months and non-traumatic ON of the femoral head which progresses to a collapse of the femoral head and subsequent degenerative arthritis of the hip^{1,3,4,7,10,11}). Several authors consider it an early and possibly reversible phase of ON.

The findings of marrow edema in MR images are characteristic and different from the class C ON(fluid nature confined to the necrotic portion of the femoral head)by Mitchell et al⁶). The marrow edema is more wide spread including the metaphyseal area of the femur and is a transient phenomenon which later resolves spontaneously. The relationship between marrow edema and ischemic insult and its possible role in the pathogenesis of ON are poorly understood.

This study indicates that marrow edema frequently appears during the progression of ON and it is combined with an elevation of IOP and aggravation of symptoms. Core decompression can ameliorate marrow edema relieving pain and intraosseous hypertension. But this improvement appears to be transient. After the occlusion of the decompression tract by fibrous plug and a newly formed thin cortical bone along the decompression tract, marrow edema can recur and core decompression cannot prevent it permanently.

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조기 대퇴골두 무혈성괴사에서의 골수부종의 출현 (자기공명영상을 이용한 전향적 연구)

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조기 대퇴골두 무혈성괴사 진행과정중 골수부종의 출현을 알아보기 위하여 조기 대퇴골두 무혈성괴사로 진단된 32명 환자 36 고관절에 대하여 3개월 간격으로 자기공명영상을 이용한 전향적 연구를 시행하였다. 이들중 18예에서는 핵심 감압술과 골수압 측정을 시행하였으며 나머지 18예중 증상이 있었던 예들은 보존적 요법으로 치료하였다. 자기공명영상에서의 골수 부종의 기준은 T1 강조영상에서 신호강도가 감소되고, T2강조영상에서 신호강도가 골수와 같거나 증가된 상태이며 이같은 변화가 괴사부주위의 대퇴골두와 경부 그리고 전자부위를 포함한 경우로 하였다. 8예에서는 처음 검사상 골수부종이 동반되었으며 그 중 7예는 증상이 있었다. 이들중 4예에서 핵심감압술을 시행하였고 3예에서 신속한 증상의 호전이 관찰되었다. 처음검사상 골수부종이 없었던 28예중 14예는 검사후 핵심감압술을 시행하였고 나머지 14예는 증상이 있는 경우 보존적 요법을 시행하였다. 이들중 4예에서 추적 자기공명검사상 골수부종이 관찰되었고 그 중 2예는 동통이 동반되었다. 골수부종이 출현한 기간에 4예는 핵심감압술을 받았고 이들의 골수압측정 결과는 36-60mmHg(평균 49)였다. 또한 3예는 골수부종이 출현한 기간에 고관절 전치환술을 받았다. 이들 7예의 조직검사 소견상 괴사부위 주변의 골수에 호산성의 혈장과 유사한 수액의 존재가 관찰되었고, 이는 골수부종과 부합되는 소견으로 생각되었다. 이 연구는 대퇴골두 무혈성 괴사가 진행되는 동안 근위 대퇴골의 골수 부종이 동반될 수 있으며 이 경우 흔히 골수압의 증가와 통증이 동반된다는 사실과, 핵심감압술은 골수부종과 그에 따른 통증을 신속히 감소시키지만 이 효과는 일시적이며 핵심감압술이 골수부종을 영구히 막지는 못 한다는 사실을 시사하고 있다.