

Osteonecrosis of the femoral head in spontaneously hypertensive rats

Relation to ossific nuclei during growth

Toru Hirano, Katsuro Iwasaki, Junji Oda and Toshiyuki Kumashiro

We observed the distribution of the ossific nuclei and the occurrence of osteonecrosis in the femoral capital epiphysis of spontaneously hypertensive rats. In 270 femoral heads, the ossific nuclei were seen in the following sites of the epiphysis: Type 1, the lateral portion in 150 femoral heads; Type 2, the central

portion in 5 heads; Type 3, both lateral and central portions in 12 heads; and Type 4, throughout the epiphysis in 62 heads. The number of femoral heads with osteonecrosis in Types 1-4 was 61, 0, 5, and 17, respectively.

Department of Orthopedics, Nagasaki University School of Medicine, 7-1 Sakamoto-machi, 852 Nagasaki City, Japan
Tel +81-958 47 2111 ext. 2945. Fax +81-958 43 5991
Submitted 91-03-21. Accepted 91-08-23

Spontaneously hypertensive rats (SHRs) are a model for essential hypertension in man (Okamoto and Aoki 1963). Osteonecrosis occurs frequently in the femoral heads of SHRs during the early stages of growth (Hirano et al. 1988, Iwasaki and Hirano 1988). It occurs exclusively in the femoral capital epiphysis, and gradually undergoes repair by invasion of vascular-rich granulation tissue with osteoid formation. The lesion seems similar to Perthes' disease.

We have conducted a histologic study to determine the ossification of the femoral capital epiphysis and the osteonecrosis in ossific nuclei using a large number of growing male SHRs.

Materials and methods

Totally, 135 male, 5-week-old SHRs were purchased from Charles River Japan Co., Ltd. (Kanagawa, Japan). All the rats were kept in ordinary cages, and received a standard-stock chow diet. A total of 10, 10, 10, 10, 20, 40, and 25 SHRs were killed under ether anesthesia at the ages of 6, 7, 8, 9, 10, 12, 15, and 20 weeks, respectively. For histologic studies, both femurs were removed from all the rats. The proximal femurs were fixed in 10 percent formalin and embedded in paraffin after decalcification. Then, thin coronal sections including the teres ligament were prepared and stained with hematoxylin-eosin. These sections were used to observe the following: the distribution of the ossific nuclei in the femoral capital

epiphysis and the occurrence of osteonecrosis in each ossific nucleus.

Osteonecrosis was defined as the widespread disappearance of osteocytes from the lacunae of bone trabeculae, with the bone marrow showing necrosis of hematopoietic cells or various forms of repair tissue (Figure 1).

Results

The ossific nuclei had appeared at the age of 6 weeks in six out of 20 femoral heads and in all the femoral heads at the age of 20 weeks. The sites of the ossific nuclei could be divided into four types (Figure 2):

Type 1. The ossific nucleus was located in the lateral portion of the epiphysis.

Type 2. The ossific nucleus was located around the insertion of the teres ligament.

Type 3. The ossific nuclei were seen in both the lateral and the central portions of the femoral head.

Type 4. The ossific nucleus was a single mass throughout the epiphysis.

The rate of appearance in the Type 4 site had increased markedly at the age of 15 and 20 weeks. The ossific nuclei did not occur in 41 femoral heads (Table 1).

Osteonecrosis was recognized in 83 femoral heads after the age of 7 weeks (Table 1), with a peak of 46 percent at the age of 15 weeks. Of five femoral heads with necrosis in the Type 3 sites, three femoral heads

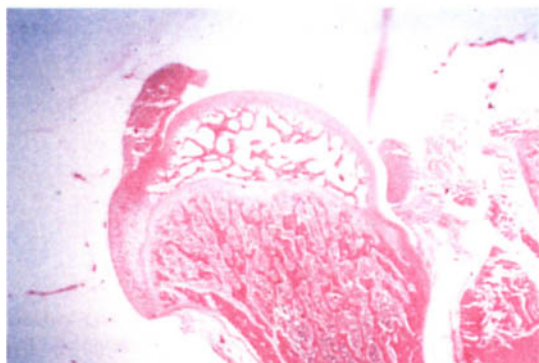


Figure 1. A. Osteonecrosis in the femoral capital epiphysis of a 9-week-old SHR. HE stain, x13.



Figure 1. B. High magnification of the lesion. Osteocytes in bone trabeculae and bone marrow cells have undergone complete necrosis. HE stain, x200.

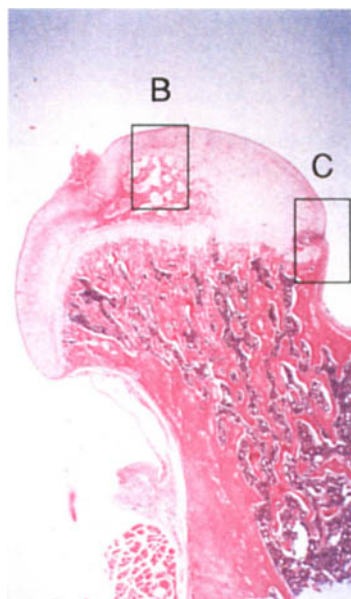
Table 1. Number of femoral heads (with osteonecrosis) in each type by age

Ossific nucleus Type	Age (weeks)								
	6	7	8	9	10	12	15	20	Total
1	4	9 (1)	11 (3)	12 (5)	11 (2)	28 (15)	53 (28)	22 (7)	150 (61)
2	1	1	3						5
3	1	2	3 (2)	1	1 (1)	1	2 (1)	1 (1)	12 (5)
4		1 (1)		3 (1)	2	6 (1)	23 (8)	27 (6)	62 (17)
No ossific nucleus	14	7	3	4	6	5	2		41

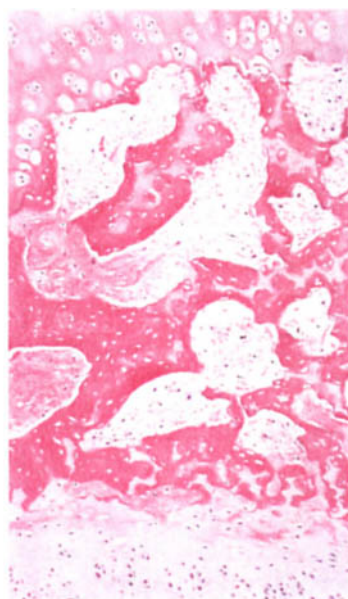
Figure 2. Blood vessels feeding the ossific nuclei in the femoral capital epiphysis of SHRs.

L.E.V. The lateral epiphyseal vessels.

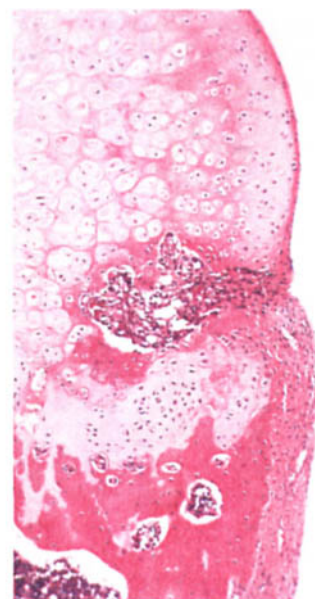
T.L.V. The teres ligament vessels.



A. Ossific nucleus in the central and lateral portions of the femoral head. x13.



B. Osteonecrosis occurring in the ossific nucleus of the central portion. x100.



C. The ossific nucleus of the lateral portion. No osteonecrosis is seen here. x100.

Figure 3. Type 3 ossific nuclei in both the lateral and central portions of the femoral head. HE stain.

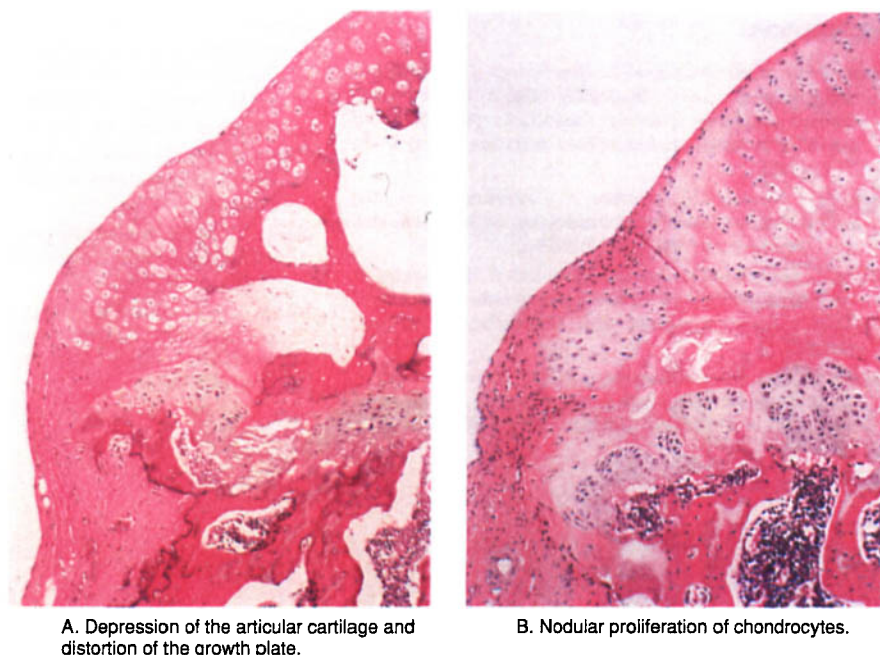


Figure 4. The changes in the cartilage of the femoral heads. HE stain, $\times 100$.

at 8, 15, and 20 weeks showed necrosis that occurred only in the ossific nuclei of the central portion (Figure 3), whereas the remaining two femoral heads at 8 and 10 weeks manifested necrosis that occurred only in the ossific nuclei in the lateral portion. In the Type 4 site, the lesion extended throughout the epiphyseal nuclei in 15 of 17 femoral heads with necrosis. However, in two femoral heads at 7 and 15 weeks, necrosis was seen in part around the insertion of the teres ligament.

Associated with necrosis, the changes in the cartilage, such as disorganized patterns and nodular proliferation of chondrocytes in the growth plate and depression of the articular cartilage, were frequently seen in the lateral side of the femoral heads (Figure 4). However, in the femoral heads where the necrosis was restricted to areas around the insertion of the teres ligament, there were no abnormalities in the cartilage.

Discussion

The femoral capital epiphysis in growing SHR receives its blood supply from either the lateral epiphyseal vessels or the teres ligament vessels, or both. Trueta (1957) reported that in children over 4

years of age the epiphyseal nuclei were usually nourished by the lateral epiphyseal vessels and the teres ligament vessels. Therefore, the blood supply to the femoral capital epiphysis in SHR would be similar to that in children.

Hirano et al. (1989) suggested that the occlusion of the lateral epiphyseal vessels occurred in the region between the articular cartilage and the growth plate where the cartilage forms a canal. They assumed that the occlusion was due to the destruction of the canal, because abnormal findings, such as disorganized patterns and nodular proliferation of chondrocytes, were frequently seen there. However, the cause of the necrosis in the ossific nuclei around the insertion of the teres ligament has not been discussed. It appears that the cause of the occlusion of the teres ligament vessels was different from that of the lateral epiphyseal vessels, because no abnormalities were seen in the cartilage near the teres vessels. Other factors, such as an increase in intraarticular pressure and a specially forced posture of the hip, may take part in the occlusion of the teres ligament vessels, as suggested by Tachdjian and Grana (1968), Henard and Calandruccio (1970), Kemp (1981), Vegter and Lubsen (1987).

References

- Henard D C, Calandruccio R A. Experimental production of roentgenographic and histological changes in the capital femoral epiphysis following abduction, extension, and internal rotation of the hip. *J Bone Joint Surg (Am)* 1970; 52 (3): 600-1.
- Hirano T, Iwasaki K, Yamane Y. Osteonecrosis of the femoral head of growing, spontaneously hypertensive rats. *Acta Orthop Scand* 1988; 59 (5): 530-5.
- Hirano T, Iwasaki K, Sagara K, Nishimura Y, Kumashiro T. Necrosis of the femoral head in growing rats. Occlusion of lateral epiphyseal vessels. *Acta Orthop Scand* 1989; 60 (4): 407-10.
- Iwasaki K, Hirano T. Osteonecrosis and ossification disturbance of the femoral head in spontaneously hypertensive rats. *Nippon Seikeigeka Gakkai Zasshi* 1988; 62 (11): 1003-10.
- Kemp H B. Perthes' disease: The influence of intracapsular tamponade on the circulation in the hip joint of the dog. *Clin Orthop* 1981; 156: 105-14.
- Okamoto K, Aoki K. Development of a strain of spontaneously hypertensive rats. *Jpn Circ J* 1963; 27 (3): 282-93.
- Tachdjian M O, Grana L. Response of the hip joint to increased intraarticular hydrostatic pressure. *Clin Orthop* 1968; 61: 199-212.
- Trueta T. The normal vascular anatomy of the human femoral head during growth. *J Bone Joint Surg (Br)* 1957; 39 (2): 358-94.
- Vegter J, Lubsen C C. Fractional necrosis of the femoral head epiphysis after transient increase in joint pressure. An experimental study in juvenile rabbits. *J Bone Joint Surg (Am)* 1987; 69 (4): 530-5.