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Acetabular dysplasia in the rat induced by injury to the triradiate growth cartilage

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An extraarticular lesion of the physeal component of the acetabular roof was performed by thermal cautery in young Wistar rats. Seventy-four animals were studied. The effects of the lesion on the pelvis, the hip joint, and the femur were analyzed during a 14-week period by radiographic, gross morphologic, morphometric, and histologic methods. Most hips developed dysplasia with a shallow and deformed acetabulum and a deformed and underdeveloped femoral head.

Harrison (1958, 1961) and Ponseti (1978) described the triradiate cartilage as a complex of physeal and epiphyseal cartilages that not only separates the growing bones of the pelvis, but also gives the characteristic cup shape to the acetabular walls. The lateral part of the horizontal limb of this complex with extraarticular physeal and intraarticular epiphyseal cartilage plays an important part in the development of the acetabular roof. The gradual change of the acetabular roof to its final appearance and its potential lesions are of special interest (Laurenson 1965). Different grades of acetabular dysplasia could be induced by performing lesions to the labrum (Negri et al. 1977, Kim 1987) or to the chondroosseous components of the acetabular roof (Soini and Ritsilä 1984). These authors considered the labrum a basic component of the acetabular roof.

In rats, we have studied the effects of a thermal cautery lesion of the physeal extraarticular component of the acetabular roof on the development of the pelvis and hip joint.

Materials and methods

Eighty-two 21-day-old Wistar rats were divided into 3 groups: the experimental group A of 65 rats, the sham-operated on group B of 9 rats, and the control group C of 8 rats.

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Group A. Under ether anesthesia the skin was shaved and a longitudinal incision was made anterolaterally over the hip joint. The triradiate cartilage was exposed at the acetabular roof (Figure 1). A 2-mm long and deep lesion was made over the exposed portion of the triradiate cartilage. A thermal cautery (Martin Elektron 120) equipped with a 1-mm thick and 2-mm long terminal was used with the aid of a stereomicroscope (Zeiss OP Mi NAG 50 VA). The hip-joint capsule was inspected to insure that no articular injury had been caused. Eight rats were

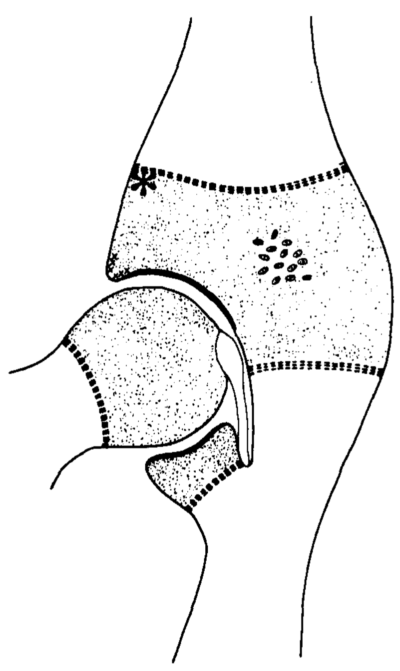

Figure 1. The frontal section of the hip region of a rat showing the zone of lesion (asterisk).

discarded because of a joint injury or bleeding. Six rats were killed on the 1st, 2nd, 3rd, 4th, 6th, 8th, 10th, and 12th weeks, 5 at the 13th week, and 4 rats on the 14th week. Twenty animals were used for morphologic and morphometric studies, and the remaining 37 were processed for histologic study.

Group B. In sham-operated on rats, the triradiate cartilage was not injured.

Group C. In the control rats, no operation was performed.

All the rats

A posteroanterior radiographic projection was taken using a Hewlett-Packard x-ray system, 43805 Faxitron Series, and mammography films (Mammoray RP3, Agfa Gevaert). The acetabular index was measured with reference to the line following both ischial tuberosities and the line of both superior and inferior edges of the acetabulum. The CE angle was determined with the perpendicular to the biischial line through the center of the femoral head and from the center of the acetabulum to the superolateral edge. The presence of acetabular dysplasia and of subluxation or dislocation of the hip was evaluated.

The gross morphology of the hip joint, femoral head and neck, acetabulum, pulvinar (fibrofatty tissue of the fossa acetabuli), ligamentum teres, transverse ligament of the acetabulum and acetabular rim of 20 animals was examined with the stereomicroscope.

A nonius caliper (Zürcher Modell, Dentarium 042-751) was used to measure the long axis of the innominate bone, ilium, ischium, and iliopubic ramus, the obturator foramen diameters, the acetabulum diameters and depth, and the femoral head diameters. A plastic goniometer was used to evaluate the angles of bending of the innominate bone in the lateral and posterior planes. The measurement of the acetabular anteversion angle was performed by placing the pelvis between two methacrylate-perforated plates. These were 6 cm wide and 5 cm high, separated by 5 cm from each other and secured to a base. The holes in the plates were spaced 2 mm apart and formed Cartesian coordinates in every plate. The sagittal midline axis of the pelvis specimen and the line following the anterior and posterior edges of the acetabular rim were determined. The acetabular anteversion angle was measured using both axes.

A histologic study was performed in 37 animals of group A. Frontal and transverse sections of the specimens were made, fixed in a 10 percent formalin solution, decalcified in a 7 percent nitric acid solution, and embedded in paraffin for study under the microscope. Five-micron thick serial sections were stained with hematoxylin and eosin and Masson trichrome.

The results were processed in the calculation center of our hospital. IBM DSP IF programs and two-way contingency tables were used for the statistical analyses. Qualitative measurements were compared with the control groups using the chi-square test, and quantitative measurements were compared with the Student's *t*-test.

Results

No radiographic, morphologic, or morphometric differences were found between the two control groups; hence, the animals of both groups could be pooled to form a single control group.

Radiographic results. In group A, dislocation of the hip was found in 10 of 57 rats, subluxation in 19 rats, and 5 had poor coverage; this gave a total of 34 of 57 rats with acetabular dysplasia (Figure 2). The congruency was abnormal in 21 of the 57 rats, and coverage was poor in 30 rats. The acetabular index in the test group was on an average 84°, i.e., increased compared with the control value of 77° (Table 1). In the test group the CE angle was much lower, with an average value of 1° compared with 15° in the right

Table 1. Acetabular dysplasia in the rat. Radiographic results. Mean *SD* (degrees)

	Test group	Control	*P*-value
Acetabular index	84 *8*	77 *4*	< 0.01
CE angle	1 *14*	8 *5*	< 0.05
Neck-shaft angle	135 *6*	131 *5*	< 0.03

Table 2. Morphometric results.[a] Mean *SD*

	Test group	Control
Acetabular depth	2.2 *0.3*	2.6 *0.4*
Femoral head diameters		
Vertical	2.9 *0.4*	3.5 *0.6*
Horizontal	3.3 *0.4*	3.9 *0.7*
Sagittal	3.3 *0.5*	3.8 *0.6*
Femoral width		
Diaphyseal	2.9 *0.3*	3.5 *0.7*
Metaphyseal	4.9 *0.4*	6.1 *0.9*
Lateral bending of innominare bone	18.2 *7.5*	14.7 *3.3*

[a]All longitudinal parameters are expressed in mm. Lateral bending is expressed in degrees. $P < 0.01$ for all comparisons between test group and control.

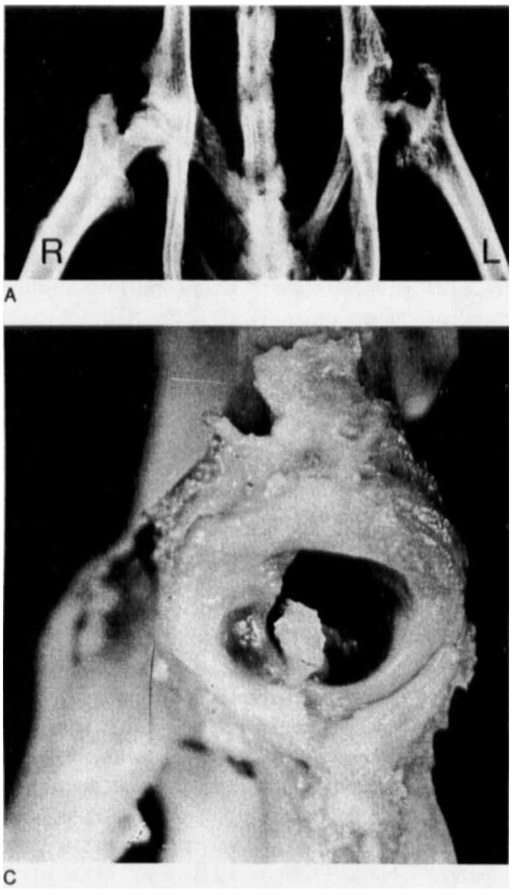

Figure 2. An acetabular physeal lesion was performed in the left hip.
A. Posteroanterior radiograph of both hips showing acetabular dysplasia and subluxation of the left hip.
B. Anteroposterior photograph of both femoral heads showing a small head and superior flattening and thickening of ligamentum teres on the left.
C. Lateral photograph of the left acetabulum showing thickening of the hip-joint capsule and rounding and flattening of the acetabular rim at its superior zone.

uninjured side and 8° in the control series. In 35 hips the femoral head was smaller, and in 24 hips a typical flattening on the top of the femoral head was observed (Figure 2). Further, in 29 hips the femoral neck presented anomalies, usually a narrowing. Finally, the neck-shaft angle was increased in the test group.

Morphologic results. The ligamentum teres was thicker in the 20 test specimens studied and longer than in the control group ($P < 0.01$). The acetabular fat pad was usually hypertrophied less than 6 weeks after the injury, and was fibrous and almost avascular 8 or more weeks after injury. Rounding and flattening of the acetabular rim presented (Figure 2) in 12 hips ($P < 0.01$). Finally, the development of a limbus was observed in 9 hips, a ridge or neolimbus appeared in 5, and a neoacetabulum in 4.

Morphometric results. Only the lateral bending of the innominate bone showed a difference ($P < 0.01$) compared with the control series (Table 2). In the acetabular measurements, only the decrease in depth was

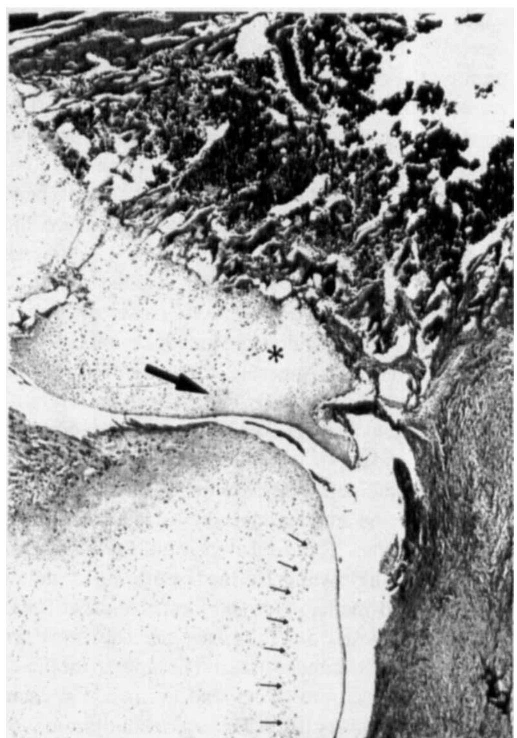

Figure 3. Coronal section of a specimen 4 weeks after an acetabular physeal lesion. Necrosis of the lateral part of the growth plate of the triradiate cartilage (asterisk), of the adjacent articular cartilage of the the acetabulum (arrow), and of the superior pole of the femoral head (small arrows). HE, x120.

significant ($P < 0.01$) when compared with the control series. The femoral head was smaller in all 20 cases and in all three of its diameters when compared with the controls ($P < 0.01$; Figure 2). The femur was narrower than in the controls ($P < 0.01$; Table 2).

Histologic results. In the area next to the lesion, necrosis of the lateral part of the growth plate of the triradiate cartilage was observed (Figure 3). At the acetabulum, a fibrous reaction of the fatty pad was noted during the first few weeks, which diminished with time. Fibrosis of the hip-joint capsule was noted. A zone of necrosis of the articular cartilage adjacent to the zone of necrosis of the growth plate was also noted. In addition, the femoral head exhibited a zone of necrosis in its superior pole, with flattening of the cartilage and reduced size. The epiphyseal ossification center was smaller and the growth plate was shorter than on the control side.

Discussion

Previous studies of experimental lesions of the triradiate cartilage (Hallel and Salvati 1977, Negri et al. 1977, Soini and Ritsilä 1984, Gepstein et al. 1984) emphasize the development of hip dysplasia and dislocation as a result of the lesions. On the whole, our findings agree with the results of these authors.

Deformities appeared in the femoral head. The smaller size and superior flattening were constant and homogeneous. A delay in the maturity of the femoral head was evident, as shown by a delay in the appearance and development of the epiphyseal ossification center and the growth plate. The small size of the femoral head may be associated with two possible causes; first, it is well known that the growth of the femoral head out of the acetabular socket diminishes its size, and secondly, a compromise of the femoral head blood supply may contributed to its reduced growth.

References

Gepstein R, Weiss R E, Hallel T. Acetabular dysplasia and hip dislocation after selective premature fusion of the triradiate cartilage. An experimental study in rabbits. J Bone Joint Surg (Br) 1984;66(3):334–6.

Hallel T, Salvati E A. Premature closure of the triradiate cartilage. A case report and animal experiment. Clin Orthop 1977;(124):278–81.

Harrison T J. The growth plate of the pelvis in the rat. A mensural and morphological study. J Anat 1958;92:236–60.

Harrison T J. The influence of the femoral head on pelvis growth and acetabular form in the rat. J Anat 1961;95: 12–24.

Kim Y H. Acetabular dysplasia and osteoarthritis developed by an eversion of the acetabular labrum. Clin Orthop 1987;(215):289–95.

Laurenson R D. Development of the acetabular roof in the fetal hip. An arthrographic and histological study. J Bone Joint Surg (Am) 1965;47:975–83.

Negri C, Tricarico A, Iorio L. The importance of the acetabular rim in the genesis of congenital hip dysplasia. Experimental research. Ital J Orthop Traumatol 1977;3(2): 219–25.

Ponseti I V. Growth and development of the acetabulum in the normal child. Anatomical, histological, and roentgenographic studies. J Bone Joint Surg (Am) 1978;60(5): 575–85.

Soini J, Ritsilä V. Experimentally produced growth disturbance of the acetabulum in young rabbits. Acta Orthop Scand 1984;55(1):14–7.

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