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ON THE DEVELOPMENT OF THE EPIPHYSIS OF THE FEMORAL HEAD FOLLOWING DISLOCATION OF THE HIP JOINT IN YOUNG RABBITS

By

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INTRODUCTION

In a previous paper (*Bohr, Baadsgaard & Sager* 1965) it was shown that dislocation of the hip joint in new born rabbits results in interruption of the vascular supply to the femoral head and ischemic necrosis of the epiphyseal bone. During revascularization it was demonstrated that vessels from the metaphyseal side perforated the epiphyseal plate with the formation of temporary bone bridges between the meta- and epiphysis. Upon the disappearance of these perforations within the first 4 weeks following the dislocation only little disturbance in the development of the epiphyseal bone was seen, showing that sufficient blood supply was established.

The present investigation deals with the development and structural changes in the epiphyseal bone after dislocation of the hip joint in one week old rabbits, studied by means of Tetracycline labelling and microradiography.

MATERIAL AND TECHNIQUE

One week old rabbits had the right hip dislocated through gentle manipulation with pressure on the adducted femur. A slight click was felt at the dislocation, which was confirmed on X-ray photos. The animals moved freely and were able to support themselves on both legs shortly after the dislocation. In one experiment 7 rabbits

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of two different litters had an injection of "Reverin" (Pyrrolidino-methyl-tetracyclin) 12.4 mg subcutaneously either on the day before dislocation of the hip or at different days after dislocation. In another experiment 6 animals from one litter had an injection of "Reverin", 12.5 mg subcutaneously the day before dislocation, and some of the animals had a further one or two injections of "terramycine" (Oxytetracycline) 12.5 mg subcutaneously on different days following the dislocation, as seen in the table, where the animals have been arranged according to age at sacrificing.

The animals were killed by an overdose of Nembutal and permanent dislocation of the hip was controlled on X-ray photos of the intact animals. A careful dissection of the hip joints was performed with observations of the deformities and the development of the head and the neck of the femur as well as the acetabulum. Following removal of the femur, X-ray photos of the femoral head were made and after fixation and dehydration the proximal part of the femur was embedded in Methylmethacrylate. Sections were cut in the frontal plane with a rotating saw and after grinding under water to a thickness of 50 μ, microradiography was performed using a Machlett X-ray tube, A.E.G. 50, supplied with a Wolfram anode generated at 12 kV and 10 mA. Exposures were made on Kodak Spectroscopic plates 649–0, at a film-focus distance of 15 cm and with an exposure time of 10 min. The sections were then mounted on glass slides with "Depex" and the fluorescence in ultraviolet light observed using secondary Reichert filters OG1 and GG9. Two or three sections of each speciment were examined.

Table 1.

Animal No.	Label before disloc.	Label after disloc.	Killed after disloc.	Semicircular "ring" from label before disloc.
1	0	R. 1 day	2 days	
2	R. 1 day	0	3 days	+
3	R. 1 day	0	6 days	+
4	R. 1 day	0	7 days	+
5	0	R. 7 days	9 days	
6	R. 1 day	T. 9 days	10 days	+
7	R. 1 day	0	11 days	0
8	0	R. 9 days	13 days	
9	R. 1 day	T. 9 + 13 days	14 days	0
10	0	R. 13 days	15 days	
11	R. 1 day	T. 13 + 17 days	18 days	0
12	R. 1 day	T. 18 + 22 days	24 days	0
13	R. 1 day	T. 24 + 28 days	35 days	0

Labelling of animals with Reverin (R) and Terramycin (T).

The results are indicated as presence (+) or absence (0) of semicircular fluorescent "ring" corresponding to enchondral ossification before the dislocation of the hip joint.

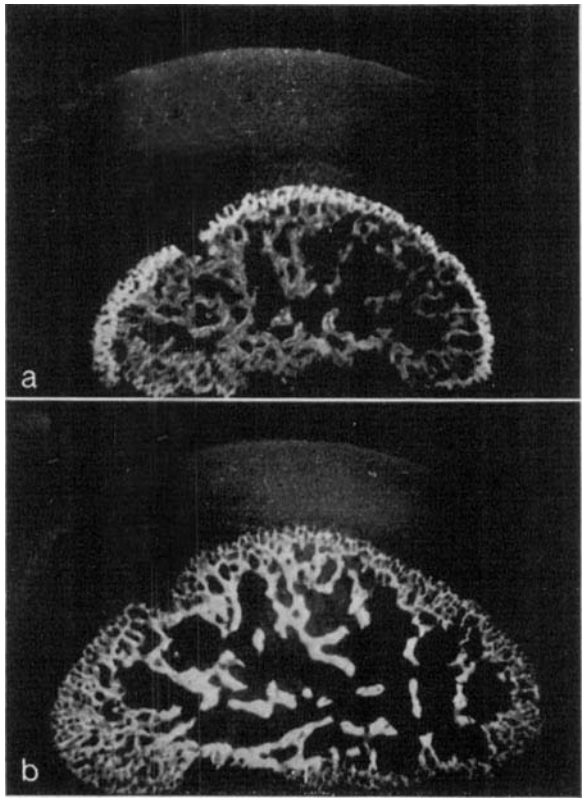

Figure 1 a. Fluorescence photo from the right femoral head in animal No. 3, labelled with "Reverin" 1 day before dislocation of the right hip and sacrificed 6 days after dislocation. The semicircular "ring" from enchondral ossification line labelled before the dislocation is undisturbed. Magnification × 20.

Figure 1 b. Fluorescence photo from the left femoral head (control side) in animal No. 3. Magnification × 20.

RESULTS

At the dissection it was seen that a new acetabulum above and behind the original had already developed three days after the dislocation of the hip joint and during the following week a nearthrosis was established. The femoral head showed slight varus position and anteversion from the second week after dislocation and at the same time shortening of the femoral neck took place. Furthermore an increased growth of the minor trochanter was constantly observed. In most cases the ligamentum teres was torn, and where it remained it was atrofied and with-

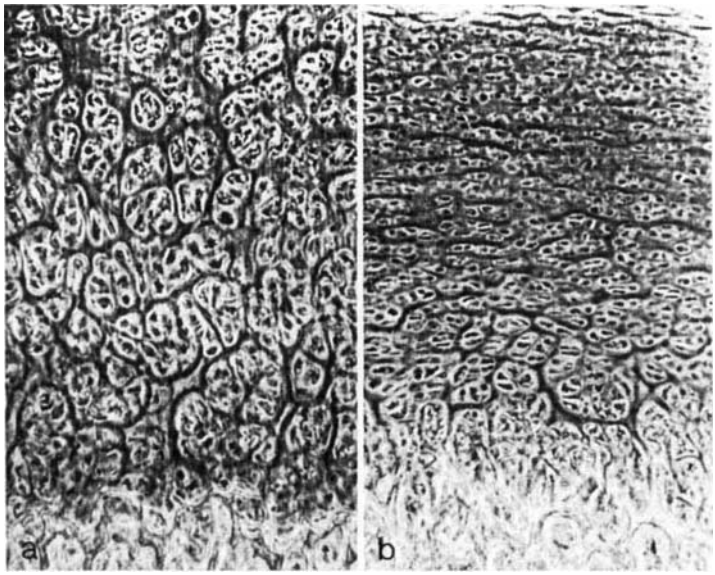

Figure 2 a. Phase contrast photo of the articular cartilage of the right femoral head in animal No. 3, showing increased layer of hypertrophic cartilage cells. Magnification × 120.

Figure 2 b. Phase contrast photo of the articular cartilage of the left femoral head (control side) in animal No. 3. Magnification × 120.

out visible signs of persisting vessels. On radiographs the epiphyseal bone of the dislocated femoral head appeared distinctly diminished and showed some sclerosis during the first two weeks after dislocation, but later regained normal size although with a somewhat deformed shape.

From fluorescence microscopy it can be seen that the uptake of "Reverin" in the epiphyseal bone the day before dislocation remains almost undisturbed in the femoral head during the following week. Thus the previous enchondral ossification below the articular cartilage persists in the right femoral head as a semicircular fluorescent ring, while this "ring" disappears in the normal epiphysis of the left femoral head due to continued growth (Figures 1a and 1b). Despite the inhibition of ossification processes it can be seen that the articular cartilage of the right femoral head increases in thickness as compared with the control side. This is due to proliferation of the cartilage cells with formation of an increased layer of hypertrophic cells in the stage preceding enchondral ossification (Figures 2a and 2b).

At the beginning of the second week following dislocation revascular-

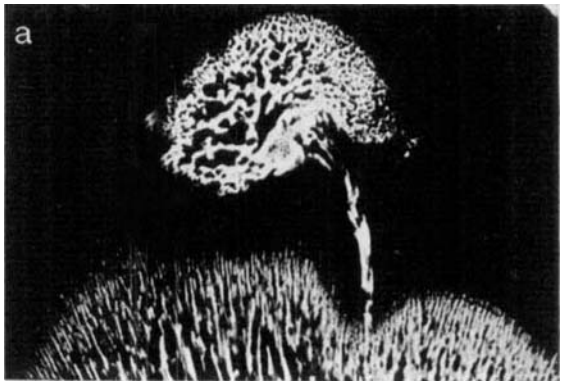

Figure 3. Microradiograph of the right femoral head in animal No. 10, sacrificed 15 days after dislocation of the right hip. A bone bridge is established corresponding to perforation of vessels through the epiphyseal plate from the metaphysis to the epiphyses. Magnification × 10.

ization of the epiphyseal bone takes place partly through vessels perforating the epiphyseal plate, and the establishment of temporary bone bridges between the meta- and epiphysis will be demonstrated by microradiographic examination at a somewhat later stage (Figure 3). As bone formation is resumed and calcification around the hypertrophic cartilage cells takes place, the semicircular "ring" from the previous enchondral ossification labelled before dislocation is seen inside the new developed bone (Figure 4). From the corresponding microradiograph it appears that the density of the bone structure is increased compared with the control side (Figures 5a and 5b).

During reconstruction of the epiphyseal bone the semicircular "ring" is broken (Figure 6), and as indicated in Table 1 it disappears from the second week after dislocation. In the following weeks osteoporosis and defects in the original epiphyseal bone result from an increased resorption (Figures 7a and 7b). Gradually the bone structure is reorganized leaving only small fragments of the original epiphyseal bone within the depositions of new bone (Figure 8).

DISCUSSION

Following dislocation of the femoral head with interruption of the vascular supply to the epiphyseal bone (*Bohr, Baadsgaard & Sager* 1965) the ossification process stops; this is seen most clearly from the

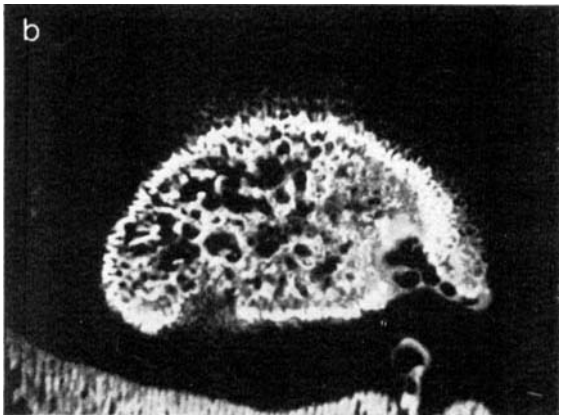

Figure 4. Fluorescence photo of the right femoral head in animal No. 6, labelled with "Reverin" 1 day before dislocation of the right hip and with "Terramycin" 9 days after dislocation. Sacrificed 10 days after dislocation. The semicircular "ring" from enchondral ossification labelled before dislocation persists inside the new developed bone giving the appearance of "Head in the head". Magnification × 20.

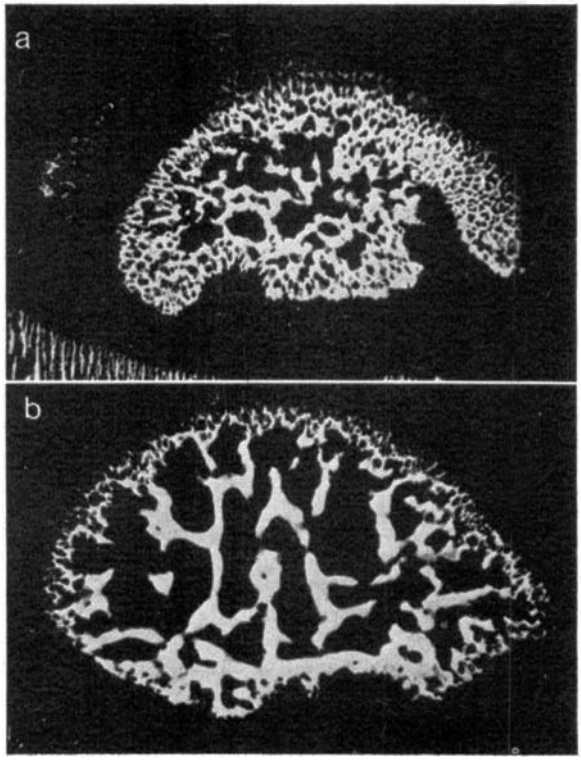

Figure 5 a. Microradiograph of the right femoral head in animal No. 6, corresponding to Figure 4, and showing increased density of the bone structure. Magnification × 20.
Figure 5 b. Microradiograph of the left femoral head in animal No. 6. Magnification × 20.

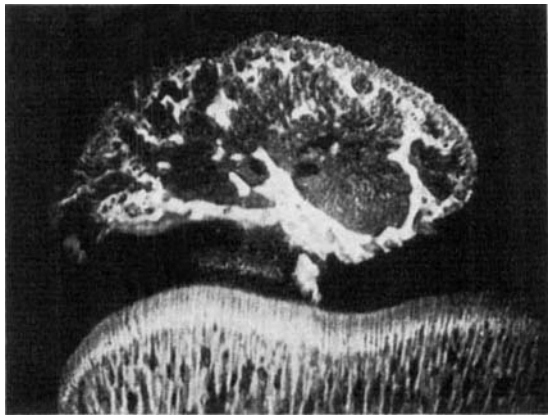

Figure 6. Fluorescent photo of the right femoral head in animal No. 9 labelled with "Reverin" the day before dislocation of the right hip and with "Terramycin" 9 and 13 days later. Sacrificed 14 day after dislocation. It is evident that the semicircular fluorescent "ring" from "Reverin" is broken and that enchondral ossification has been resumed. Magnification × 12.

persistence of the fluorescent "ring" corresponding to the enchondral ossification during labelling the day before dislocation (Figure 1a). With revascularization ossification is resumed in conformity with the vascular contribution to osteogenesis (*Trueta* 1962), and bone formation takes place primarily as creeping apposition on the old trabeculas resulting in an increased density of the epiphyseal bone (*Bobechko & Harris* 1960, *Hulth* 1961 and *Bohr & Larsen* 1965). In the case of a young growing organism an image of the original epiphyseal bone is left inside the new developed bone, giving the appearance on X-ray photos of a "head within the head" (*Salter* 1966). Such an image may be either positive or negative depending on whether appositional or resorption processes prevail. In the present investigation a positive "head in the head" can be observed during the time when the semicircular "ring" from the previous enchondral ossification remains (Figure 5a). With the disappearance of this "ring" a negative "head in the head" is seen due to the increased resorption (Figure 7a). During the following period new bone trabeculas are formed and the structure is normalized, although some deformity of the femoral head may result. The observation that proliferation of the cells of the articular cartilage continues despite devascularization of the epiphyseal bone supports previous findings (*Bohr, Baadsgard & Sager* 1965 and *Slätis & Rokkanen* 1966) and indicates that independent nutrition of the growing cartilage may take

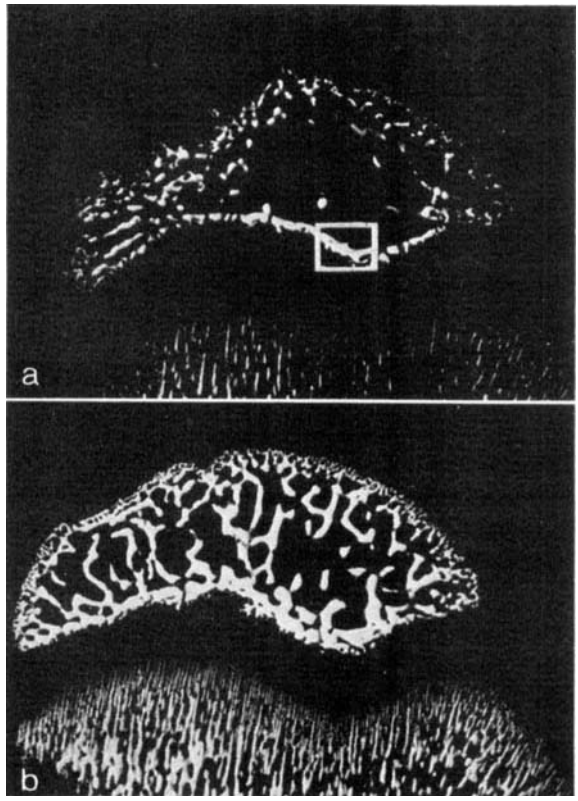

Figure 7 a. Microradiograph of the right femoral head in animal No. 12, sacrificed 24 days after dislocation of the right hip. Osteoporosis and defects of the original epiphyseal bone can be seen. Magnification × 10.

Figure 7 b. Microradiograph of the left femoral head in animal No. 12. Magnification × 10.

place probably from the synovial fluid (*Ingelmark* 1950, *Ekholm* 1951 and *Brower, Akahoshi & Orlic* 1962).

These results may be compared with the dyplastic changes in the femoral head, which occur in relation to congenital dislocation of the hip joint in humans where the phenomenon of a "head within the head" is often observed. From the evidence of the present investigation the appearance of a positive or a negative "head in the head" may be explained owing to impairment of the vascular supply to the femoral head.

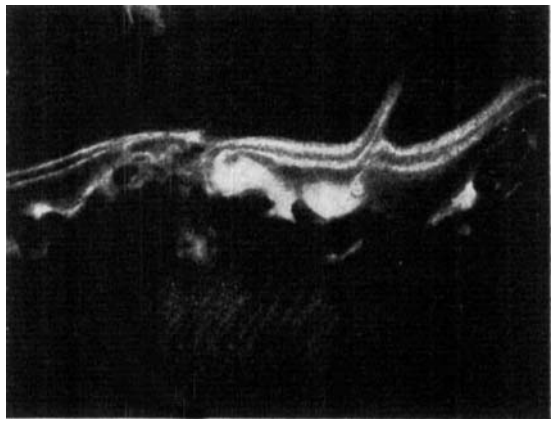

Figure 8. Fluorescent photo of the right femoral head in animal No. 12 corresponding to the enframed area on Figure 7 a. Small fragments of bone diffusely labelled with "Reverin" before dislocation of the right hip are left inside depositions of new bone between lines of "Terramycin" labelling 18 and 22 days after dislocation. Magnification × 50.

SUMMARY

In one week old rabbits dislocation of the right hip joint with disruption of the vascular supply to the femoral head was performed, and the development and structural changes of the epiphyseal bone were studied by means of Tetracycline labelling and microradiography. The results compared with the normal development on the control side show that the ossification processes stop leaving the previous enchondral ossification undisturbed during the following week, although the proliferation of the cells in the articular cartilage proceeds. With revascularization 1–2 weeks after dislocation, partly through vessels perforating the epiphyseal plate, reconstruction of the epiphyseal bone takes place. Primarily an increased density of the epiphyseal bone is seen due to appositional bone formation. This is followed by osteoporosis with defects due to resorption of the original epiphyseal bone and with disappearance of the previous enchondral ossification line. The course of events is discussed in relation to the phenomenon of a "head within the head", seen following congenital dislocation in humans.

RESUME

Chez des lapins âgés d'une semaine, il a été provoqué une dislocation de l'articulation droite de la hanche avec rupture de l'approvisionnement vasculaire à la tête fémorale afin d'étudier le développement et les changements structuraux de l'os épiphysaire au moyen de la coloration à la tétracycline et de la microradiographie. Les résultats comparés au développement normal du côté de contrôle montrent que le processus de l'ossification s'arrête, laissant l'ossification enchondrale antérieure inchangés durant la semaine suivante bien que la prolifération des cellules dans le cartilage articulaire ait progressé. Avec la revascularisation 1–2 semaines après la dislocation, en partie par des vaisseaux ayant perforé la plaque épiphysaire, une reconstruction de l'os épiphysaire commença. Primairement, on observa une densité accrue de l'os épiphysaire due à une formation osseuse appositionelle. Cela fut suivi d'ostéoporose avec des défauts dus à la résorption de l'os épiphysaire original et à la disparition de la ligne d'ossification enchondrale antérieure. Il est discuté de l'évolution du processus en relation avec une "téte à l'intérieur de la tête" observée après une dislocation congénitale chez les humains.

ZUSAMMENFASSUNG

Bei eine Woche alten Kaninchen wurde eine Luxation des rechten Hüftgelenkes mit Unterbrechung der Gefässversorgung zum Femurkopf ausgeführt und die Entwicklung und Strukturveränderungen des Epiphysenknochens mittels Tetracyklinmarkierung und Mikroradiographie studiert. Die mit der normalen Entwicklung auf der Kontrolseite verglichenen Resultate zeigen, dass der Ossifikationsprozess aufhört und dass die vorgehende enchondrale Ossifikation während der folgenden Woche ungestört belassen wird, während die Proliferation der Zellen im Gelenksknorpel fortschreitet. Mit der Revaskularisierung 1–2 Wochen nach der Verrenkung beginnt die Rekonstruktion des Epiphysenknochens, teilwiese durch Gefässe die die Epiphysenplatte durchbohren. Anfänglich wird eine erhörte Dichte des Epiphysenknochens wegen übermässiger Knochenbildung gesehen. Dieser Periode folgt Osteoporose mit Defekten wegen Resorption des ursprünglichen Epiphysenknochens und unter Verschwinden der vorhergehenden enchondralen Ossifikationslinie. Der Verlauf des Geschehens wurde unter Bezugnahme auf die Erscheinung des "Kopfes innerhalb des Kopfes", die man nach angeborener Hüftverrenkung bei Menschen sieht, besprochen.

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