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DENSITOMETRY AND 18-F SCINTIGRAPHY IN THE STUDY OF THE REVASCULARIZATION OF THE FEMORAL HEAD IN COXA PLANA (C-P)

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Despite the great number of publications concerning Coxa Plana since it was first described very little is known about the etiology and course of this disease. Without entering further into the different opinions about the significance of trauma, synovitis or growth disturbance, it seems to be confirmed that partial or total necrosis takes place in the epiphysis of the femoral head, probably due to failure of the blood supply. (Howorth 1948, Jonsäter 1953, Goff 1954, Trueta 1957, Ponsetti & Cotton 1961). The further development of C-P therefore depends on the reestablishment of vascularization.

From different sides it has been shown that the increased density of the bone tissue, which appears following necrosis, is due to the apposition of new living bone tissue upon the old necrotic trabeculae and is thus a result of revascularization (Bobechko & Harris 1960, Hulth 1961, Bohr & Hjalmar Larsen 1965). In order to study this in relation to C-P, densitometric measurements of the epiphysis of the femoral head have been made during the condensation stage. Further, the vascular supply has been studied in different stages of C-P through scintigraphy with radioactive fluorine.

MATERIAL AND METHODS

Patients with C-P have for many years been treated with prolonged bed rest at The Seaside Hospital at Refsnæs, subject to regular check-ups by radiography of the hip. Since 1970 densitometric measurements have been made on the X-ray photos using a calibration with ivory step wedges to determine the density of the bone structure photometrically (Mack et al. 1949, Henny 1950). The step wedges were placed under the buttocks during exposure of the film to get their projections

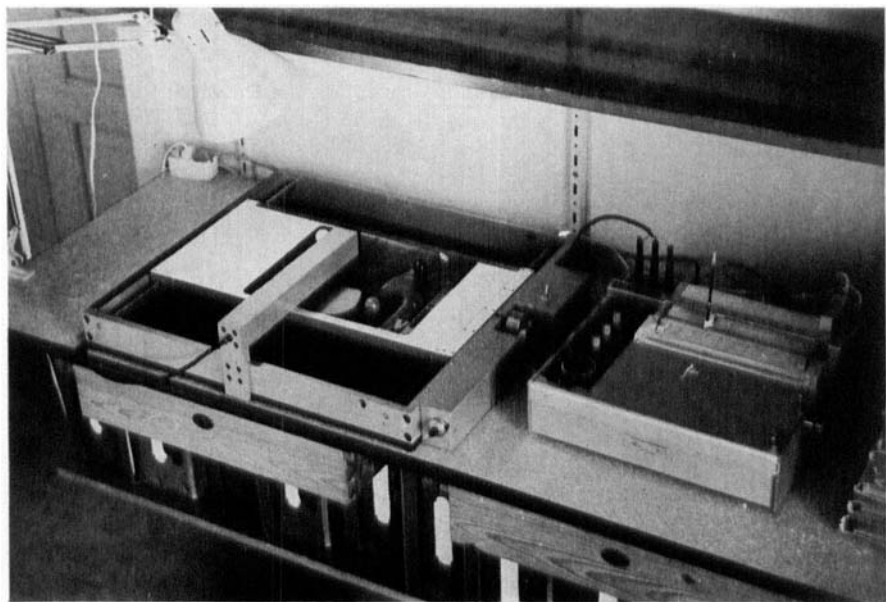


Figure 1. Densitometer with photometer and potentiometer-recorder.

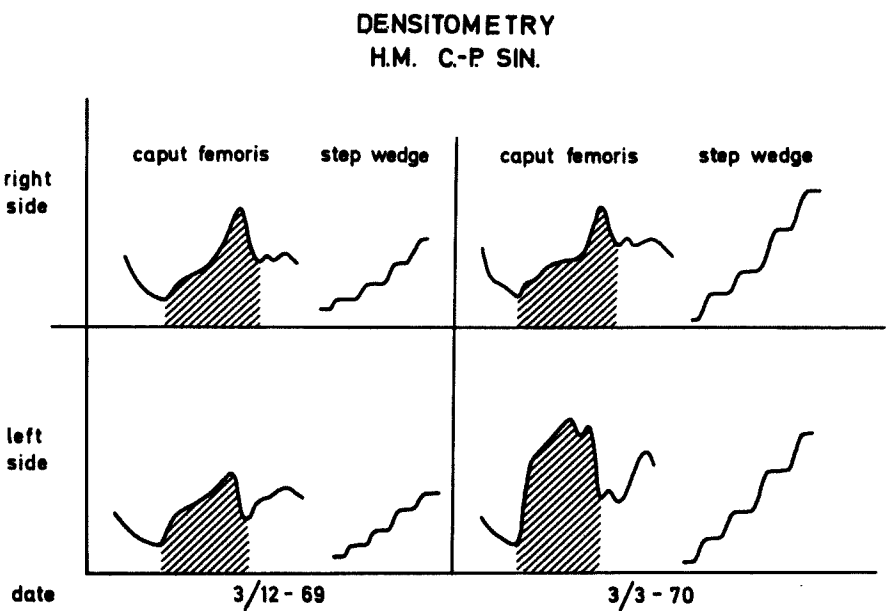


Figure 2. Densitometric measurements in a 7-year-old boy with C-P. (case no. B 19307, Table 1). Hatched area represents a sagittal section through the middle of the epiphyseal bone. Ivory step wedges shown to the right.

close to the femoral head at the inside of the femoral neck, as seen in Figures 4 and 6. Two identical step wedges were used, one on each side, to compensate for differences with regard to exposure of X-rays and thickness of soft tissue. The radiograph was evaluated with a photometer, manufactured for this purpose, so that the film was guided automatically between a light-source and a photocell, and the intensity of the transmitted light in a 2 mm broad zone was recorded with a potentiometer (Figure 1). From the absorption of the X-rays the density of the bone present can be determined, provided the area of bone is known.

The measurements covered a sagittal section through the middle of the epiphysis and the corresponding bone area was measured with a planimeter on X-ray photos in the Lauenstein projection. The density of the epiphyseal bone was determined by comparison with measurements on the ivory step wedges as seen in Figure 2, and expressed in arbitrary units. In all, several hundred measurements of this kind were performed and through repeated determinations the accuracy is estimated to be about ± 5 per cent.

Scintigraphic investigations were made with radioactive fluorine (^{18}F), a positron emitter with a half life of 1.8 hours, registering the gamma rays of 510 MeV produced through annihilation. Radioactive fluorine was produced in a cyclotron at the Niels Bohr Institute by bombardment of neon with deuterons and is delivered as a sterile product in a 0.1 parts/ 10^3 solution of NaF. An amount of 2 mc ^{18}F was given i.v., corresponding to a radiation dose of 0.5 rad to the skeleton (Blaux et al. 1962, Spencer et al. 1967). Scanning of the hip joints was performed one hour after the injection of the isotope, using a scannomat from Siemens A/S supplied with two 5 inch scintillation-crystals, or an Ohio scanner with two 8 inch crystals. Recordings were made with a detector both above and below the patient, simultaneously.

RESULTS

In Table 1 the results of the densitometric measurements on the epiphysis of the femoral head are given for 13 cases of unilateral C-P, admitted to the hospital during the early condensation stage. The measurements on the initial X-ray photos show that the density on the diseased side almost always is greater than on the healthy side and on the average shows an increase of 36 per cent, which is statistically significant. Following three months of strict bed rest it is seen that the density of the epiphysis on the diseased side sometimes increases a little and sometimes falls, but on the average is unchanged. On the other hand the density on the healthy side decreases in every case, on the average by 35 per cent in relation to the initial measurements, showing the amount of osteoporosis during immobilization (Bohr 1972).

Thus at the time of admission to the hospital an increased density of the epiphysis of the femoral head is present on the diseased side in relation to the healthy side, and the condensation appears to be real and not apparent. As the patients in the present investigation had been

Table 1. Densitometric measurements of the epiphysis of the femoral head in C-P during the condensation stage.

Case no.	Initial measurements		Measurements 3 months later	
	diseased side	healthy side	diseased side	healthy side
B 19307	19	14	19	10
B 19371	19	19	23	7
B 19427	21	20	19	12
B 19445	14	10	16	7
B 19490	21	15	14	7
B 19526	16	10	14	6
B 19568	23	14	26	12
B 19594	17	19	19	10
B 19599	16	9	18	7
B 19732	17	11	17	8
B 19771	22	14	20	10
B 19779	19	13	18	11
B 19887	17	11	17	9
mean value	19 ± 1.3	14 ± 1.0	19 ± 0.6	9 ± 0.6

admitted directly to the hospital and only in a few cases had been in bed for more than four days before the initial X-ray photos were taken, it seems unlikely that osteoporosis of the healthy side could have occurred.

The scintigraphic investigations were performed in 10 cases representing different stages of C-P. In a case of early condensation where

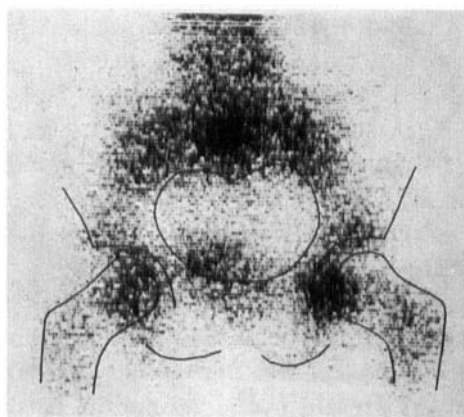
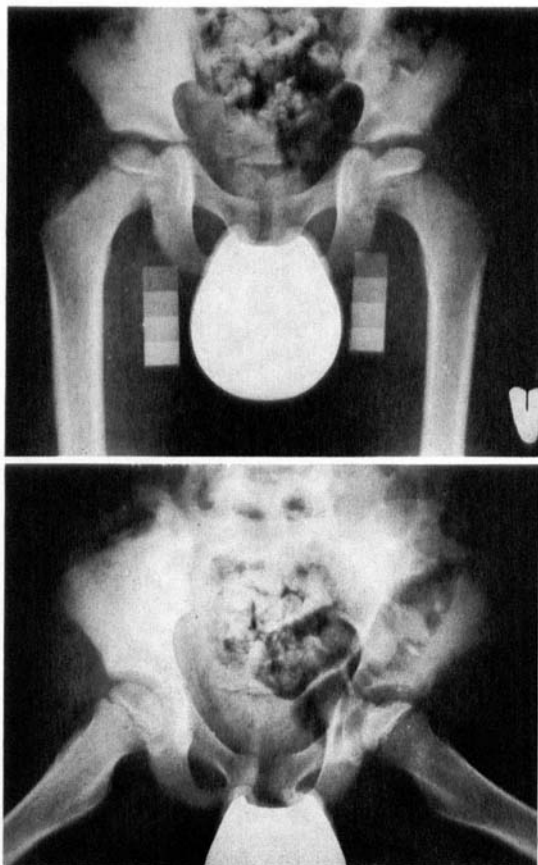


Figure 3. Scintigraphy with ^{18}F in an 8-year-old boy with C-P seen during condensation stage (case no. 19887, Table 1). Distinct uptake in the metaphysis and in the medial part of the left epiphysis, but reduced uptake in the lateral part of the epiphysis.

Figure 4. Radiographs of the hips corresponding to Figure 3.



the investigation was performed immediately after admission to the hospital the scintigraph is demonstrated in Figure 3 and the corresponding radiograph in Figure 4. It is seen that there is a distinct uptake of radioactive fluorine on the diseased side especially in the metaphysis and the medial part of the epiphysis, whereas the lateral part of the epiphysis shows only little uptake compared with the healthy side. In four cases of late condensation with incipient fragmentation the uptake in the metaphysis and the medial part of the epiphysis was increased compared with the healthy side, while the uptake in the lateral part of the epiphysis was still somewhat reduced. Four cases were examined during fragmentation and showed increased uptake in the metaphysis and the total epiphysis as seen in the case presented in Figures 5 and 6. The same was true although to a lesser degree in the last case examined during restitution.

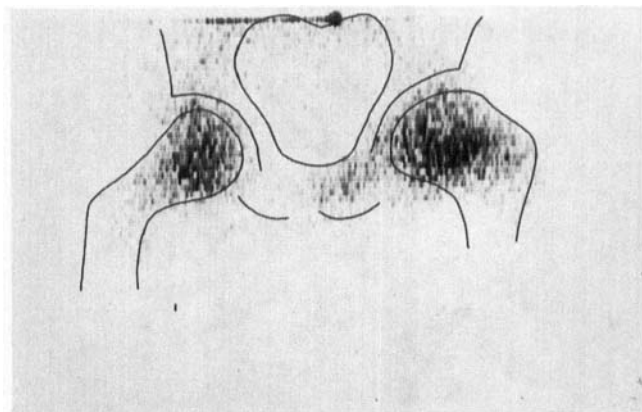


Figure 5. Scintigraphy with ^{18}F in a 9-year-old boy with C-P seen during fragmentation stage. Increased uptake in the left metaphysis and epiphysis compared with the right side.

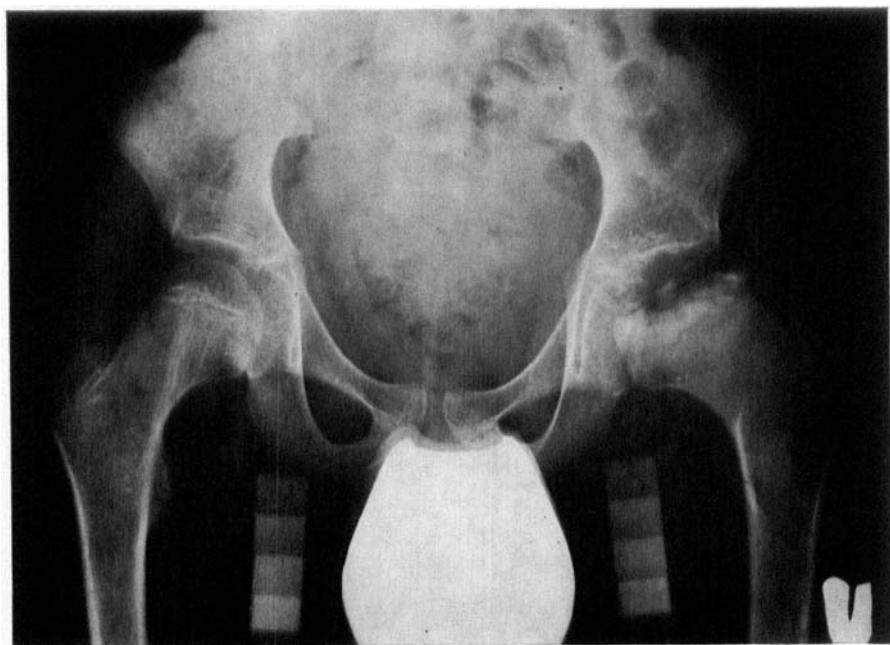


Figure 6. Radiograph of the hips corresponding to Figure 5.

DISCUSSION AND CONCLUSION

In the present investigation it has been shown that during the condensation stage the density of the bone structure in the epiphysis of the diseased side is increased compared with that of the healthy side. At the time of the initial measurements a few days after admission to the hospital, it is unlikely that the difference in density is due to osteoporosis of the healthy side and it can therefore be assumed that the bone density of the diseased side is also increased in absolute terms. As shown by various authors such increase in density of necrotic bone tissue is due to appositional bone formation (Bobechko & Harris 1960, Hulth 1961, Bohr & Hjalmar Larsen 1965) and therefore indicates that revascularization has taken place. This is supported by the results of the scintigraphic measurements where a marked uptake of radioactive fluorine could be demonstrated early in the condensation stage. It is the general opinion that the uptake of radioactive fluorine in the skeleton is due to exchange between fluorine and hydroxyions at the surface of the apatite-crystals, and measurements one hour after the injection of the isotope preferentially correspond to the degree of vascularization (French & Mc. Cready 1967, Moon et al. 1968). In the work of Jonsäter (1953) biopsies from the epiphysis of the femoral head during the condensation stage showed necrosis in all 14 cases and only in 3 cases living bone was present. These findings which seem to contradict the present result may represent an earlier stage of the disease, since Jonsäter states that the symptoms had occurred only three months before the biopsies were taken, whereas the densitometric measurements of the present investigation were carried out on the average four months after the onset of the first symptoms. It is more likely, however, that the biopsies, which according to Jonsäter were taken from the lateral side of the hip, represent that part of the epiphysis where the uptake of radioactive fluorine was reduced.

The densitometric measurements performed after three months of immobilization show that the bone density of the diseased side is on the average unchanged, while the density of the healthy side is reduced by 36 per cent showing the amount of osteoporosis due to immobilization. The fact that osteoporosis does not affect the diseased hip despite revascularization may be due to an increased rate of bone-formation compensating for the general loss of bone.

From the above mentioned results it may be concluded that revascularization of the epiphysis of the femoral head in C-P usually has

taken place already in the stage of condensation from vessels penetrating the medial part, while the vascular supply to the lateral part seems to remain reduced for a longer time, corresponding to the greater involvement of this part of the epiphysis in the disease. These relations may be of importance in the treatment of C-P, especially as regards operations, which intend to promote revascularization.

SUMMARY

Measurements of the bone density on X-ray photos calibrated with ivory step wedges were performed on the epiphysis of the femoral head in 13 cases of C-P during the stage of condensation. It was shown that the mean value of density recorded at the time of admission to the hospital was increased by 36 per cent on the diseased side compared with the healthy side. After three months of immobilization the density on the diseased side remained on the average unchanged, while the density on the healthy side was reduced by 36 per cent due to osteoporosis. According to various authors the increase in density following necrosis of the bone is due to appositional bone formation and the present results therefore indicate that revascularization has taken place at the time of condensation. This conclusion is supported by the scintigraphic investigations with radioactive fluorine showing a distinct uptake in the metaphysis and the medial part of the epiphysis. The uptake in the lateral part of the epiphysis was reduced during the early condensation stage, but during fragmentation and restitution the uptake was increased in the total epiphysis, compared to the healthy side.

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