Acta orthop. Scandinav. *40*, 563–570, 1969

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THE EFFECT OF CO^{60} IRRADIATION ON THE PATELLA IN DOGS

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Received xi.68

As a sesamoid bone of the knee joint, the patella differs in many respects from other bones. In radiotherapy of malignant bone or soft tissue tumours of the knee, the patella, also, is frequently subjected to irradiation. Moreover, radiotherapy has long been used in the treatment of osteoarthritis of the knee joint (*e.g.* Kepp 1952, Knierer 1957), whereby the patella as a rule falls within the field of irradiation. Although, lately, the operative and medical treatment of osteoarthritis has gained ground, radiotherapy is still sometimes applied.

In previous papers the effect of Co^{60} irradiation on the menisceal tissue and on the soft tissues of the knee region (Rissanen et al. 1968, 1969a) and on cancellous and diaphyseal bone (Rissanen et al. 1969b, c) have been described. Since, however, as a sesamoid bone the patella seems to be in a special position in many respects, we have tried also to clarify the effect of Co^{60} irradiation on the patella using histological, histochemical and oxytetracycline[1] (OTC)-labelling methods and microradiography.

MATERIAL AND METHODS

The material consisted of 12 dogs of different breeds, *i.e.* six adult dogs aged 2–11 years and six growing dogs aged about three months at the beginning of the study. A 3000 Ci Tele-Cobalt Unit (FSD 75 cm, dose rate 104 rad/min) was used for irradiation. With the dogs in barbiturate anaesthesia, both knees were irradiated with fields measuring 6 cm × 10 cm, using the following single doses:

I. Adult dogs. Left knee joint, 1000 rad; right knee joint, 4000 rad.
II. Growing dogs. Left knee joint, 1000 rad; right knee joint, 2000 rad.

[1] Terramycin® intramuscular Pfizer.

The material was divided into three groups according to the time of sacrifice: (A) four days after irradiation; (B) two weeks after irradiation; (C) two months after irradiation.

The samples collected for histological and histochemical studies were fixed in neutral formalin, decalcified by the EDTA method and stained by the Weigert-van Gieson haematoxylin-eosin, and alcian blue techniques. For OTC fluorescence studies the dogs were given 20 mg of oxytetracycline two days before sacrifice. The samples for these studies and for microradiography were hardened with methylmetacrylate and ground to 100 μ thickness. In microradiography the following values were used: 15 mA, 24 kV, 5 min, FSD 12 cm.

RESULTS

I. *Adult Dogs*

A. Four days after irradiation the following changes were noted: Histologically and histochemically, the articular cartilage was uniform after irradiation with 1000 rad, but staining was poor in areas. After 4000 rad, fragmentation was observed in the superficial layers of the articular cartilage. The cancellous spaces were acellular, but the bone was normal after irradiation with these doses. After 4000 rad, incipient regeneration of the bone was seen subchondrally. OTC fluorescence was evenly distributed at the margins of the bone trabeculae after both 1000 rad and 4000 rad. In addition OTC fluorescence was observed in areas of the cancellous spaces. Microradiography revealed, after 1000 rad, an otherwise normal bone structure, but in the cancellous spaces new mineralized areas occurred. This phenomenon was more extensively observed after irradiation with 4000 rad.

B. Two weeks after irradiation the following changes were noted: Histologically and histochemically, fragmentation of the articular cartilage was seen after 1000 rad and 4000 rad. The cancellous spaces were acellular, and the bone was partly anuclear. OTC fluorescence was very scanty after irradiation with both 1000 rad and 4000 rad,

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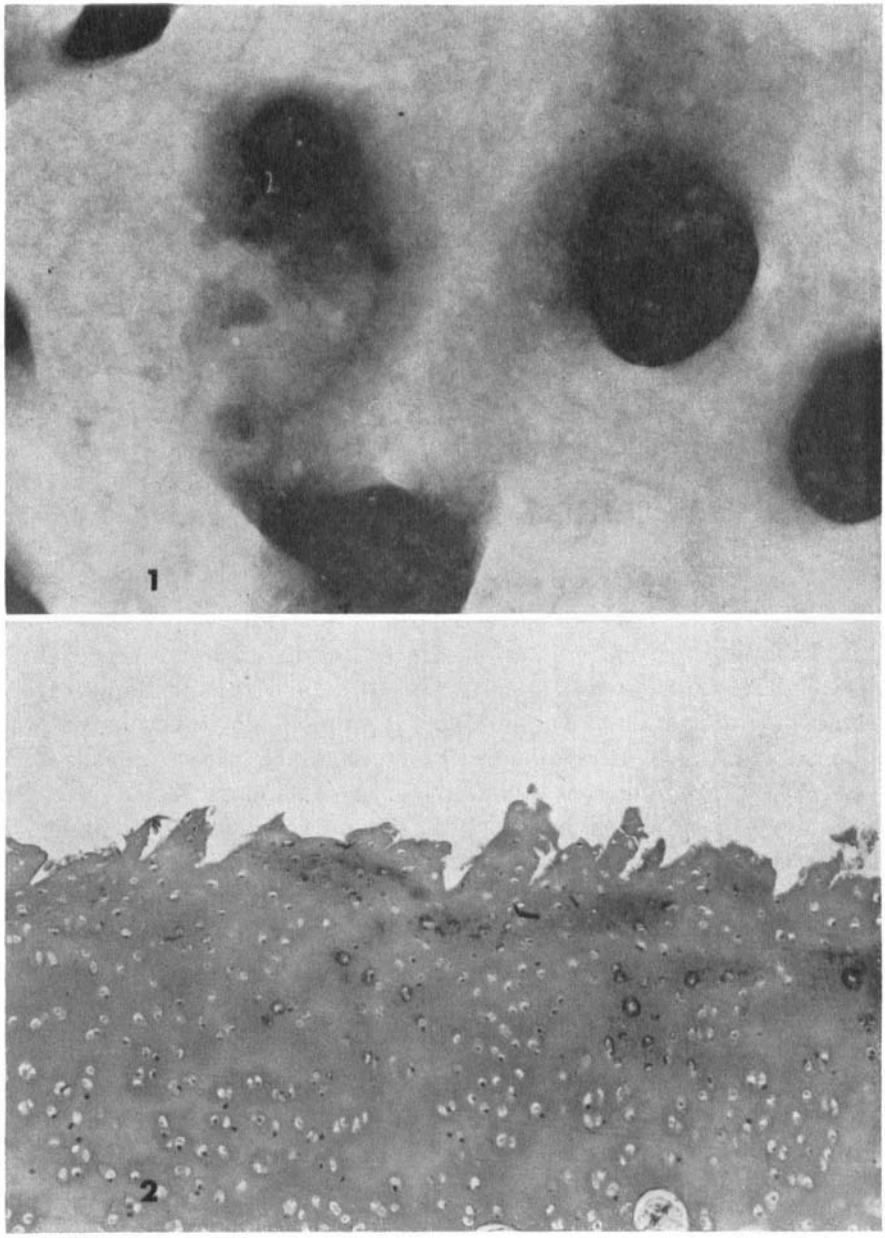
Figure 1. Microradiograph of the patella of an adult dog, taken two months after irradiation with a single dose of 1000 rad. The density of the bone trabeculae is decreased and new mineralized areas seen at their margins, signifying regeneration. × 100.

Figure 2. Micrograph of the patellar articular cartilage of a growing dog, taken four days after irradiation with a single dose of 1000 rad. The articular cartilage shows fragmentation and decreased metachromasia. Alcian blue. × 100.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except in those areas in which microradiography revealed poorly mineralized areas. Such areas were frequently seen in the cancellous spaces. After 4000 rad, in particular, the density of the bone trabeculae appeared to be decreased.

C. Two months after irradiation the following changes were noted: Histologically and histochemically, the articular cartilage cells were almost entirely anuclear after 1000 rad and 4000 rad, and the metachromasia of the matrix was weak and uneven. The cancellous spaces were empty or contained fatty tissue. The bone was anuclear and showed fragmentation in the wide areas. OTC fluorescence was observed only here and there in new mineralized areas and in certain sites at the margins of the cancellous spaces after 1000 rad, and not at all after 4000 rad. Microradiography revealed numerous new mineralized areas in the cancellous spaces after 1000 rad and 4000 rad, and the density of the bone trabeculae was reduced in areas (Figure 1).

II. *Growing Dogs*

A. Four days after irradiation the following changes were noted: Histologically and histochemically, the articular cartilage showed fragmentation after 1000 rad and 2000 rad, and the metachromasia was reduced (Figure 2). Subchondrally, aggregations of osteoblasts were seen. The cancellous spaces were poor in cells, and regeneration of the bone was observed in areas. The bone trabeculae were poor in nuclei. OTO fluorescence was evenly distributed at the margins of the cancellous spaces after 1000 rad, particularly in the subchondral area. After 2000 rad the OTC fluorescence was clearly weaker. Microradiography revealed no changes after irradiation with 1000 rad and 2000 rad.

B. Two weeks after irradiation the following changes were noted: Histologically and histochemically, the articular cartilage showed fragmentation in areas after 1000 rad, and the metachromasia was scanty and uneven. Both osteoblasts and osteoclasts were seen subchondrally. The cancellous spaces were poor in cells and contained fatty tissue. The bone trabeculae were poor in cells particularly after 2000 rad. In certain areas incipient regeneration was observed at the margins of the bone trabeculae. OTC fluorescence was strong after irradiation with 1000 rad and 2000 rad, particularly in the subchondral area (Figure 3), at the margins of the cancellous spaces, and in new mineralized areas of

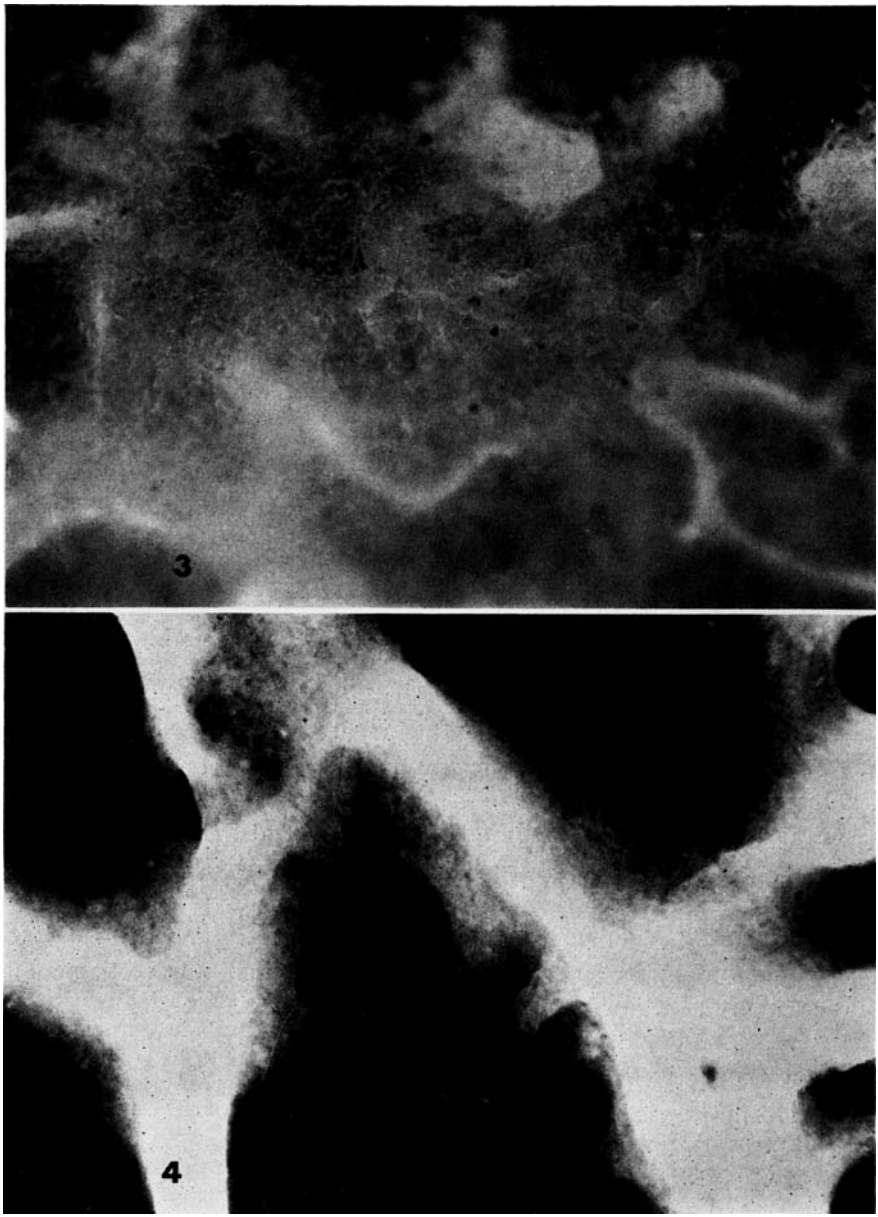

Figure 3. Fluorescence micrograph of the patella of a growing dog, taken two weeks after irradiation with a single dose of 2000 rad. Abundant fluorescence is seen subchondrally. × 100.

Figure 4. Microradiograph of the same dog as in Figure 3. Decreased density and erosions are seen at the margins of the bone trabeculae. × 100.

the latter. Microradiography showed a decrease in density of the bone trabeculae, erosions at their margins (Figure 4) and new mineralized areas in the cancellous spaces.

C. Two months after irradiation the following changes were noted: Histologically and histochemically, after 1000 rad and 2000 rad the articular cartilage cells were found to be almost entirely anuclear and metachromasia was very scanty. Very slight regeneration was observed subchondrally. The cancellous spaces were more or less empty, or they were filled with fatty tissue, and the bone trabeculae were anuclear, in particular after irradiation with 2000 rad. After 1000 rad OTC fluorescence was mostly abundant, particularly at the margins of the bone trabeculae and in poorly mineralized areas subchondrally, but areas also occurred in which fluorescence was lacking. After 2000 rad, weak fluorescence was only seen here and there. Microradiographically, after 1000 rad and 2000 rad the bone trabeculae were thin and showed fragmentation, the density was decreased, and poorly mineralized areas were observed in the cancellous spaces.

DISCUSSION

The effect of CO^{60} irradiation with single doses of 1000–4000 rad on the patella was studied in adult and growing dogs. As soon as four days after irradiation, both the adult and the growing dogs showed fragmentation and decreased metachromasia of the articular cartilage as well as degenerative changes of the bone. But at the same time signs of regeneration were also observed in the cancellous spaces. Two weeks and two months after irradiation, progression of the degenerative changes could be demonstrated both in the articular and the bone trabeculae, but the regenerative processes were also more conspicuous and extensive. The changes showed a correlation with the magnitude of the dose of Co^{60} and the age of the dogs, being more marked in the younger dogs.

On comparing the present results with the observations made in cancellous and diaphyseal bone in adult dogs (Rissanen et al. 1969b) and growing dogs (Rissanen et al. 1969c), it was found that the same doses produced clearly greater changes in both the articular cartilage and the cancellous bone of the patella. In explanation of this it may be suggested that when the entire bone is exposed to irradiation, it is not capable of resisting and compensating damages caused by irradiation as efficiently as when only part of it is irradiated. In this connection

damage caused to the surrounding soft tissues also seems to play a significant part, since with the same doses of irradiation changes were caused in these tissues (Rissanen et al. 1968, 1969a). On the basis of the present study it is not possible to answer the question as to whether the changes in the cartilage and bone are due to the direct effect of irradiation or, secondarily, to the damage caused by thrombosis of the blood vessels. Considering, however, the great changes observed in the bone at an early stage and the fact that vascular changes are a later finding, it seems probable that the bone lesions develop primarily as a result of the direct effect of irradiation on the bone, although later both factors exert a combined influence.

Since the doses of Co^{60} used in the present study were much greater than the doses used, for instance, in the treatment of osteoarthritis of the knee joint, no direct conclusions can be drawn concerning the effect of irradiation on the patella in this respect. It can, however, be maintained that the bone tissue is not in all sites nearly so resistant to irradiation as has been alleged (Clemedson & Nelson 1960, Upton 1966). Considering the striking regenerative capacity of the patella, it seems possible that irradiation of the knee with smaller doses also might promote the formation of osteophytes and thus contribute to an impairment of osteoarthritis at the patello-femoral joint. Therefore, if radiotherapy is applied to the knee region, it seems advisable to avoid irradiation of the patella. On the other hand, a normal synovial tissue reacts relatively sensitively to irradiation (Rissanen et al. 1968), which may lead to the disappearance of swelling and pain.

SUMMARY

The effect of Co^{60} irradiation on the patella in dogs was studied by histological, histochemical, and OTC-labelling techniques and by microradiography. Single doses of 1000 rad, 2000 rad, and 4000 rad were used. The dogs were sacrificed four days, two weeks, and two months after irradiation. After four days both growing dogs and adult dogs showed fragmentation and decreased metachromasia of the articular cartilage as well as degenerative changes of the bone, but signs of regeneration were also observed. After two weeks, and again after two months, both the degenerative and the regenerative changes were more marked. On comparing the changes observed with the changes caused by the same doses in cancellous and diaphyseal bone, the changes in the patella were found to be more extensive and severe.

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