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STRONTIUM-85 PROFILE COUNTING IN FRACTURES OF THE TIBIAL SHAFT

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The purpose of the present study was to evaluate the uptake of strontium in cases of fracture of the tibial shaft displaying normal healing, delayed union and non-union, and to suggest the clinical significance of the findings.

MATERIAL AND METHODS

A total of 203 strontium profile countings were made on 68 fractures of the tibial shaft in the Clinic of Surgery, University of Oulu. One injection of strontium was given in 441 cases, two injections at different stages of the healing process in 22 cases, and three injections in five cases. Of these fractures, 25 displayed normal healing, 37 displayed delayed union, and six displayed non-union.

The method employed was strontium-85 profile counting. According to Taskinen & Vähätalo (1971), this technique clearly provides more accurate information than scanning.

Strontium-85 was administered intravenously in doses of 50 μCi of strontium chloride. The measurements were made on an NaJ(T1) scintillating counter with a circular collimator 3 cm in diameter. The assays were performed on the 7th, and in 19 cases also on the 1st day after the injection of strontium. When the strontium-85 countings were made on the day after the injection of strontium, the percentage ratios (fracture/control) were low in comparison with the values obtained a week later (Figure 1). The readings were obtained from the leg at intervals of 3 or 5 cm and compared with the corresponding values for the healthy leg. The results are given as percentages of the values for the healthy leg. In addition to this, control measurements were made on each thigh at the inguinal fold and at 5 cm from the upper edge of the patella. If there was a plaster cast on the fractured leg, the healthy leg was also measured through a cast.

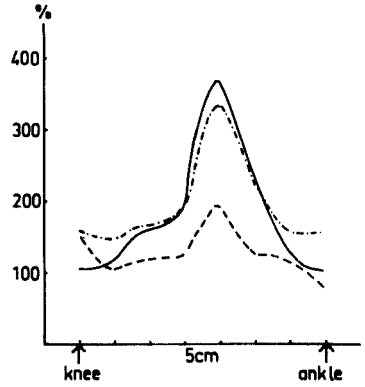

Figure 1. Transverse fracture of the tibial shaft which healed in 4 months. Strontium-85 injection was performed:
– – – – – 4 weeks after the injury (measured one day after the strontium injection).
– · – · – 4 weeks after the injury (measured one week after the strontium injection).
——— 6 months after the injury (measured one week after the strontium injection).

RESULTS

Normally-healing fractures

Normally-healing cases included the fractures of the tibial shaft which were united within 6 months. 25 cases out of the total series healed normally. Strontium-85 counting was performed at different stages of the healing process from the first days up to six months (Figure 2). In two cases the measurements were made as much as 2 years after the fracture.

When a fracture occurred, the uptake of strontium at the site of the fracture began to increase, though slowly at first. During a month after the injury, 21 profile countings in all groups showed that within the first few days strontium uptake was hardly elevated in comparison with the control leg. One week after the fracture the values were 160–180 per cent, even in delayed union. In normally-healing cases, as early as after 3 weeks the uptake of strontium increased to over 300 per cent. The peak values occurred after 4–6 months, being then of the order of 400 per cent. After 2 years the strontium accretion at the site of the fracture was still elevated (140–150 per cent).

The average activity percentage for all cases of this group was 485. Figure 1 shows the typical curves for strontium uptake. High accretion of strontium was visible at the site of the fracture after 4 weeks and 6 months. Measurements performed on the day following the strontium

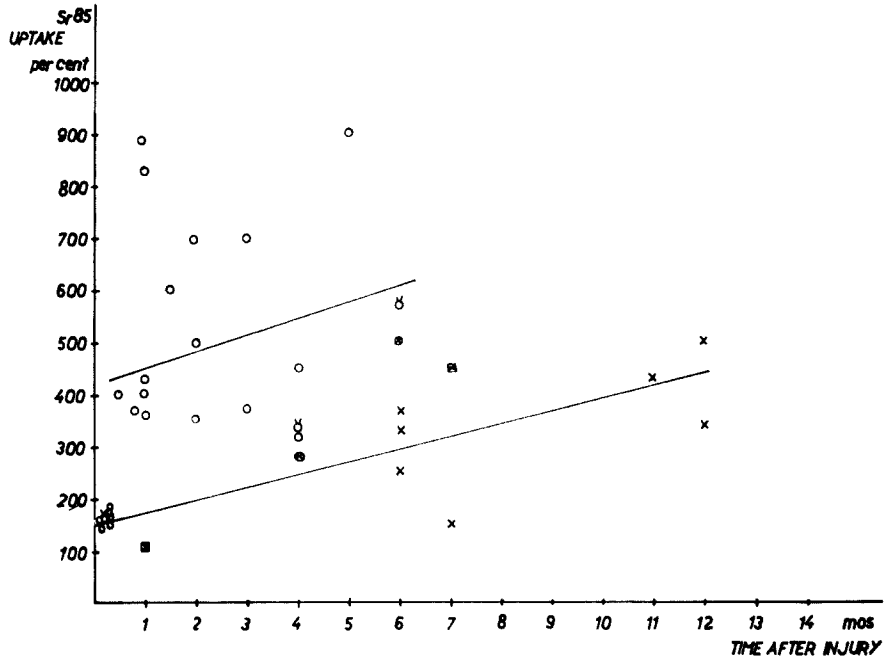

Figure 2. Regression lines indicating strontium uptake in fractures of the tibial shaft.
○ strontium uptake of one fracture with normal healing.
× strontium uptake of one fracture with delayed union treated conservatively.
ŏ, ⊠, ⊗ strontium uptake of same fracture at different times.

injection showed the relative strontium uptake to be clearly less intensive.

Delayed union

The healing of a fracture was regarded as delayed when it took more than 6 months. This group consisted of 37 fractures, 9 of which were treated conservatively and 28 by bone grafting. The choice of treatment was made on the basis of osteomedullography (Puranen & Kaski 1974).

The fractures treated conservatively were surveyed at different stages of the healing process. Although this group is too small to enable significant conclusions to be made, Figure 2 suggests, however, that the regression line indicating strontium uptake went distinctively lower in this group than in normally healing cases, but in both groups the slope of the line was the same. The average activity percentage was

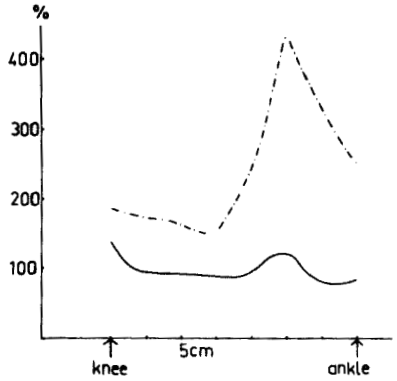

Figure 3. A fracture which healed in 9 months. Strontium-85 injection was performed:
——— 4 weeks after the injury (measured one week after the strontium injection).
– · – · – 7 months after the injury (measured one week after the strontium injection).

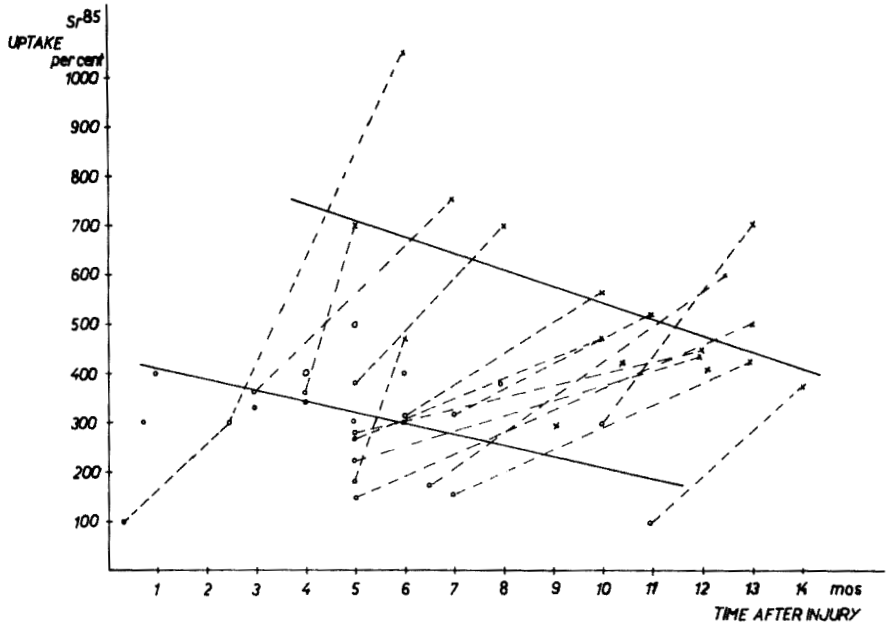

Figure 4. Regression lines indicating strontium uptake in fractures with delayed union treated by bone grafting.
○ strontium uptake before bone grafting.
× strontium uptake after bone grafting.
Dotted line unites the measurements of same fracture. Background counts of the strontium uptake before bone grafting are subtracted.

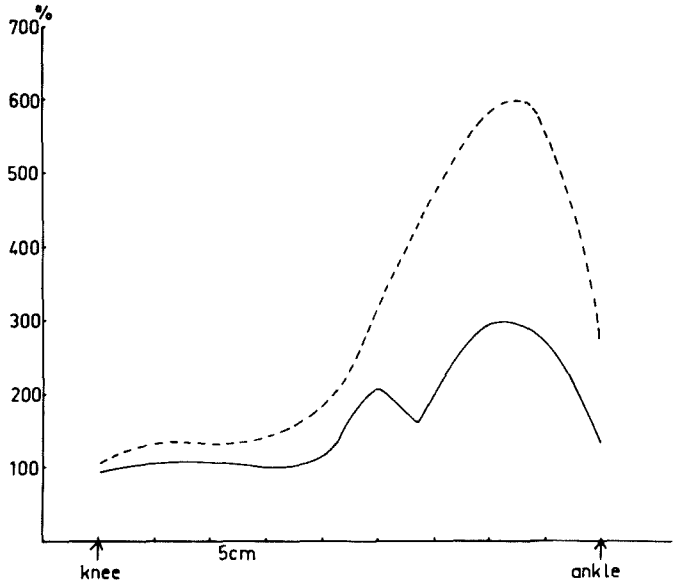

Figure 5. Transverse fracture of the lower part of the tibial shaft with delayed union.
——— Measured 1 day before bone grafting (5 months after the injury).
– – – – – Measured 3 months after bone grafting.

290. Figure 3 shows the uptake curves for a case of delayed union at 4 weeks and at 7 months after the injury. At 4 weeks the activity percentage was quite low, but at the stage where the progress of union could also be observed clinically, the percentage was clearly higher. The union was complete 9 months after the injury. In these cases the uptake of strontium was, 4 years from the date of injury, still as high as 350 per cent, although the leg was symptomless and perfectly consolidated.

In the 27 fractures which required bone grafting, most of the strontium countings were made just before the operation and about 3 months after it. In 15 cases the uptake of strontium was measured pre- and postoperatively (Figure 4). The mean activity percentage of strontium was 300 before the operation and 700 afterwards.

A typical example of the distinct increase of strontium accretion occurring after the operation is seen in Figure 5. Figure 6 shows a very high strontium uptake at the site of the fracture recorded 5 months after the injury and 3 weeks after bone grafting. The region of the knee had a similarly high strontium uptake due to a fracture of the fibular head. The region of the tibial fracture still displayed a fairly high

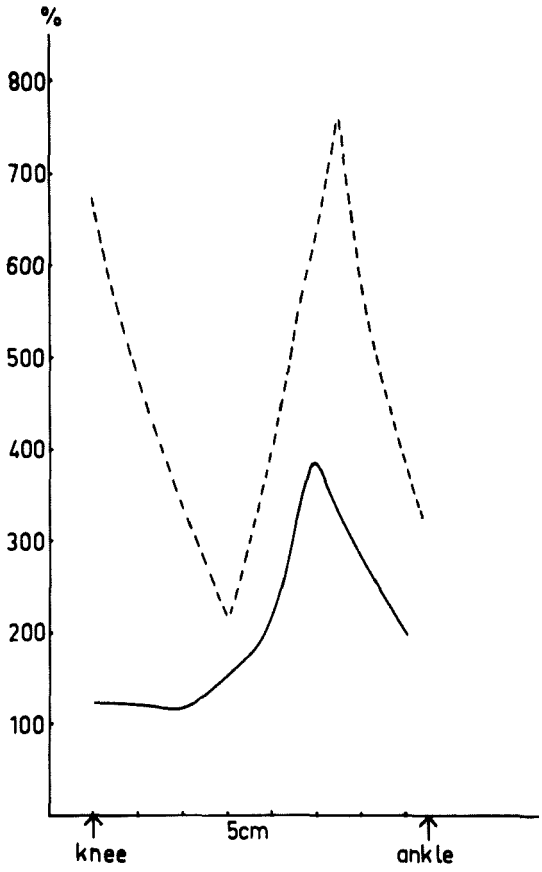

Figure 6. Transverse fracture of the tibial shaft with delayed union, and a fracture of the fibular head with normal healing. Bone transplant performed 5 months after the injury. Strontium-85 counting was performed:
– – – – – 3 weeks after bone grafting.
——— 19 months after bone grafting.

strontium uptake 24 months after the fracture, while a normally-healed fracture of the fibula at that time uptook no more strontium than did the fibula of the control leg.

In the group of fractures with delayed union, strontium uptake at the site of the fracture was still elevated four years from the date of injury. Profile counting was made in five cases after 1.5–3.3 years from consolidation, and the activity values were over 200 per cent (range 150–450 per cent).

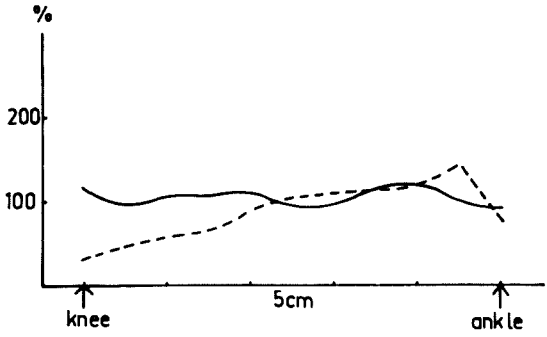

Figure 7. A 7-year-old girl with congenital pseudarthrosis of tibia. The measurements were performed before and after bone grafting. Strontium counting was made:
——— 2 days before the bone grafting.
– – – – – 2 months after the bone grafting.

Non-union

One year was arbitrarily chosen as the length of time after which the unhealed fracture was considered as a case of non-union. This series included two hypertrophic and four atrophic cases of non-union.

In both hypertrophic cases strontium uptake was preoperatively high (300 per cent). Bone grafting led to consolidation within 3 months. In atrophic pseudarthrosis, on the other hand, strontium accretion was hardly elevated in comparison with the healthy leg as measured preoperatively.

This group included one 4-year-old and one 7-year-old girl each with congenital pseudarthrosis of the tibia. Their strontium counting displayed no difference between the fractured and the healthy leg either before or after bone grafting. In both cases the transplantation failed, and the bone graft was resorbed (Figure 7).

The third case was a non-union following suppressed osteitis, and its strontium uptake was small (150 per cent). Bone grafting did not lead to consolidation, but it caused the leg to stabilize sufficiently to enable the patient to walk with support. Strontium uptake 2 years after the first bone grafting revealed a marked difference in comparison with the healthy leg (600 per cent). A new bone grafting succeeded and pseudarthrosis consolidated within 3 months.

The fourth patient of the group also had a large bone defect associated with osteitis. Strontium uptake after suppressal inflammation revealed an activity value of 140 per cent. Bone grafting was performed,

but no consolidation was seen until after 9 months, whereas it usually occurs within 3–4 months.

DISCUSSION

The present work showed that the difference in activity percentage between the fractured leg and the control leg increased as much as two- or threefold when the measurement performed on the day following the injection of strontium was repeated one week later. This is understandable, since during the first few days strontium also appears elsewhere besides being aggregated in the bones. The readings obtained during the first day are therefore merely indicative, and it is advisable to perform the strontium counting a week after the injection.

When a fracture occurred, circulation began to increase at the site of the fracture, and many times did so even in the whole of the lower limb. This was for example indicated by the elevated strontium activity of the lower limb, the average value being 130 per cent. The metabolism of the fractured bone was similarly accelerated. The measurements revealed distinct strontium uptake (approx. 180 per cent) at the site of the fracture 1 week after the injury. After 2–3 weeks the normally healing fractures began to display considerably elevated values, which reached their peak 4–6 months after the injury (400 per cent).

Elevated strontium accretion (approx. 150 per cent) at the site of the fracture was still perceptible as much as 2 years after injury. Cases of delayed union which healed with or without bone grafting displayed a fairly slow decline in strontium-85 activity, values over 200 per cent and even 400 per cent being obtained 2–3 years after consolidation of the fracture.

The present investigation gave evidence in favour of the view of Wendeberg (1961) that the ratio of strontium activity in the fracture during the healing process was consistently elevated irrespective of whether the case was a delayed union or healed normally. In the latter case, however, the ratio was higher than in delayed union. Even alkaline phosphatase activity, according to Gudmundson and Semb (1971), is significantly depressed in cases of delayed union as compared with normally healing fractures.

The regression lines (Figures 2 & 4) of the fractures with delayed union prove that the strontium uptake rose as function of time in conservatively treated fractures, but fell in fractures needing bone grafting. The explanation may be found in the progression of the

healing process. The cases of delayed union treated conservatively showed higher uptake during the existence of roentgenographic signs of consolidation than before that, when the necessity of bone transplantation was considered (Figure 6). On the other hand, in the cases which required operation for union the healing process was retarded and bone transplantation was intended as an osteogenetic stimulus to consolidation. The bone transplant was found to have a very distinct effect on the increase in the local mineral metabolism, which is shown by high strontium uptake immediately after the bone grafting (Figure 3). This lends further support to the observations made in the case of immediately transplanted bone (Puranen 1966).

The high strontium uptake at the site of the fracture means that the local osteogenetic activity of the fracture has increased. This, however, does not guarantee that the fracture will heal normally as also stated previously by Bohr (1955) and Wendeberg (1961). Although there were differences in strontium accretion between the cases of normally healing fracture and delayed union in the present investigation, they were not sufficiently pronounced to allow classification of individual fractures into different groups.

In the cases of hypertrophic pseudarthrosis, strontium uptake was increased indicating lively mineral metabolism. Bone grafting is the osteogenetic stimulus which is needed by fractures with non-union in order to consolidate. In atrophic pseudarthrosis, on the other hand, hardly any difference was seen in strontium uptake between the fractured leg and the healthy one. In such cases bone grafting did not increase strontium activity as it usually did, and the transplanted bone was even resorbed as in congenital pseudarthrosis of the tibia. The cases of non-union in our series showed that unless the activity ratio was high enough, the bone grafting did not lead to consolidation, not at the normal rate anyway. Segmüller et al. (1970) have also pointed out that strontium assay serves as a parameter of local mineral metabolism in estimating the local osteogenetic capacity of non-union. The real clinical significance of strontium counting in fractures thus lies in the fact that it helps in estimating the prognosis in fractures requiring bone transplantation.

SUMMARY

A total of 203 profile countings were performed on 68 fractures of the tibial shaft, which included 25 normally healing cases, 37 cases of delayed union, and six cases of non-union. The measurements were performed on the 1st and the 7th day after the injection of strontium. In 27 cases the fracture received 2–3 strontium injections with associated profile counting at different stages of the healing process. The cases of normally healing fractures and delayed union showed differences in the average strontium uptake. However, these differences were not distinct enough to enable classification of individual fractures into groups. In cases requiring bone grafting, the transplant was found to accelerate metabolism and increase the accretion of strontium at the site of the fracture. The investigation shows that the real value of strontium profile counting lies in its ability to give information about the osteogenetic activity of the bone, which is a necessary prerequisite for the healing of the fracture.

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