Acta orthop. scand. 44, 439–450, 1973

Departments of Orthopaedic Surgery and Medical Radiation Physics,
Lund University Hospital, S-221 85 Lund, Sweden.

# $^{85}Sr$ RADIONUCLIDE SCINTIMETRY IN INFECTED TOTAL HIP ARTHROPLASTY

GÖRAN C. H. BAUER, LARS LINDBERG, YNGVE NAVERSTEN
& LARS-OLOF SJÖSTRAND

Accepted 2.v.73

Infection following total hip arthroplasty often presents difficult diagnostic problems. Charnley (1972) has thus presented evidence that more than a third of infected total hip arthroplasties become manifest later than 18 months postoperatively, even though, in most cases, the infectious agent very probably was introduced at the time of operation. Hence, a radiographic and/or clinical diagnosis can be made only at the end of a slow and insidious disease process. It would clearly be important to establish the diagnosis infection at an earlier stage; the earlier the diagnosis is established, the better would be the chances to control the infection. Radionuclide scintimetry offers such a method. Several studies on bone infection (Bauer & Wendeberg 1959, Felländer & Lindberg 1966, Dymling & Wendeberg 1965) have demonstrated that scintimetric abnormalities may precede radiographic abnormalities; for general reasons this sequence of events is probably the rule rather than the exception (Bauer 1968, Dreyer & Georgi 1972). Now Nöh (1972) and Groher et al. (1972) have demonstrated cases of total hip arthroplasty in whom infection was accompanied by high scintimetry values. On this basis we decided to perform $^{85}Sr$ scintimetry in three series of hip arthroplasty patients, one with a normal postoperative course, one with clinically manifest infection, and one with postoperative pain but not definite infection.

---

Supported by the Swedish Medical Research Council, Stiftelsen Konsul Thure Carlssons Minne, the insurance company Förenade Liv and Alfred Österlunds Stiftelse.

## MATERIAL AND METHODS

The probands of this investigation were drawn from an ongoing prospective analysis of some 300 Charnley arthroplasties, operated here since March 1970. The progress of these patients is continuously analysed in terms of clinical signs and symptoms including radiography (Bergström et al. 1973), bacteriologic, immunologic and other chemical parameters. The results of this study will be published elsewhere.

### *Group 1, normal controls, 17 cases*

The control group was selected on the basis of the following criteria, (a) painfree or insignificant pain, never continuous, (b) ESR less than 20 mm/h, and (c) normal radiography, i.e. operation technically satisfactory, no signs of infection, no radiolucency around the endoprosthesis, nor any signs of bone formation in the soft tissues.

### *Group 2, infection manifest, 14 cases*

Among 25 cases in the prospective study who had significant pain postoperatively in spite of a technically satisfactory operation, distinction was made between those who had manifest infection (Group 2) and those who had not (Group 3). Manifest infection by definition included: (a) continuous pain, both at rest and weight-bearing, (b) ESR more than 40 mm/h when not treated with antibiotics, evidence by plasmaelectrophoresis of a highly active process, ESR preoperatively less than 20 mm/h, and (c) at least one of the following criteria, sinus formation or a progressively larger radiolucency around one or both of the components of the endoprosthesis.

### *Group 3, postoperative pain but no manifest infection, 11 cases*

The cases in this category had pain, intermittent or continuous at rest and/or weight-bearing, some had elevated ESR but none had the evidence for manifest infection as specified for Group 2, c.

### *Scintimetry methods*

Two weeks after intravenous injection of 100 $\mu$Ci $^{85}$Sr, scintimetry was performed in two modes, (1) with the detector in *fixed positions* in relation to the skeleton, and (2) with the detector *scanning* the lower pelvis and upper thigh regions including both hip joints. Prior to each scan a radiogram was made with lead indicators over the hip joints and with a long focus film distance to minimize parallactic error. The positions of the indicator were visible in the processed scans. The radionuclide uptake areas could thus be accurately localized in relation to the skeleton.

*Fixed position scintimetry* was made with a scintillation detector consisting of a 7.6 $\times$ 5.1 cm NaI (Tl) crystal equipped with a reversed conical collimator of FWHM 4 cm at 5 cm and 6 cm at 10 cm from the collimator. The standard positions (Figure 1) were (1) the vertex of the acetabular cup, (2 and 3) the femoral shaft at ⅔ and ⅓ respectively, proximal to the distal end of the stem of the endopros-

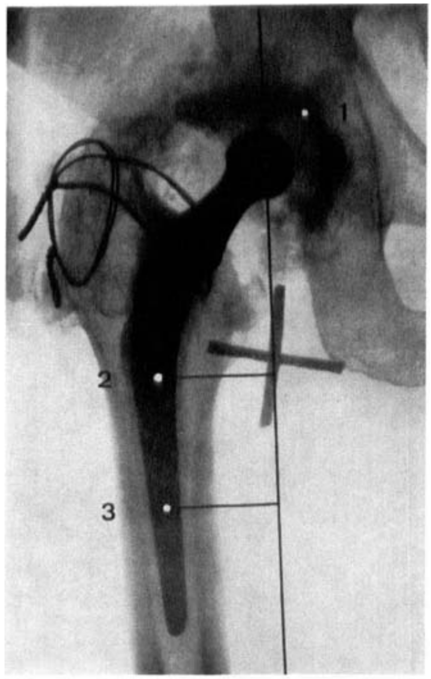



*Figure 1. Identification of landmarks for scintimetry. A radiograph of the hip region with a lead marker was obtained at long-focus-to-film distance. For fixed position scintimetry three spots were identified, (1) the vertex of the acetabular cup, and (2 and 3) over the femoral shaft at ⅔ and ⅓, respectively, proximal to the distal end of the endoprosthesis.*

thesis, and (4 and 5) over the patellae. The procedure was performed twice at each position, with repositioning in between. The counting rates were standardized with relation to decay and retention of tracer by division of the mean counting rates at positions 1 through 3 by the lowest at positions 4 and 5; the value obtained in this way was termed *activity*.

*Scan mode scintimetry* (Gustafsson et al. 1971, Naversten et al. 1972, Möller et al. 1973) was made with the crystal described above but with a coarse focusing collimator with a line spread function of about 2 cm FWHM for photons of 514 keV. The detector moved at a speed of 34 cm/min and counts collected at increments of 6 × 6 mm intermittantly were transferred to an 8 k-core memory system. Data were punched on paper tape which was fed into a terminal for computer processing that included an iterative deconvolution technique according to Metz. At the terminal, line printer outputs provided maps with iso-significant count density levels presented in different symbols and an iso-countour map from an incremental plotter.

## RESULTS

*In the normal arthroplasties (Group 1)* the initially high activity dropped to an apparently stable level which was reached at about 10 months postoperatively (Figure 2). Examples of scans in this group are shown in Figures 3 and 6.

By comparison with the uncomplicated arthroplasties, the *infected*

*Table 1. Fixed position scintimetry values in total hip arthroplasty. For definition of groups, see text and Figure 2. Activity was calculated in each case by dividing the mean values at positions 1 through 3 by that at the knee with the lowest uptake.*

| Group | Months postop. | Counts/100 s. Position 1 | Position 2 | Position 3 | Knee | Activity |
|---|---|---|---|---|---|---|
| 1 | 2 | 3435 | 1630 | 1396 | 1192 | 1.81 |
| 1 | 3 | 4552 | 3820 | 3715 | 1820 | 2.21 |
| 1 | 3 | 3804 | 4181 | 5605 | 1051 | 4.09 |
| 1 | 5 | 727 | 1115 | 1169 | 367 | 2.74 |
| 1 | 6 | 3423 | 2459 | 2054 | 899 | 2.94 |
| 1 | 7 | 2180 | 1494 | 1395 | 1051 | 1.61 |
| 1 | 9 | 839 | 863 | 484 | 367 | 1.99 |
| 1 | 10 | 1431 | 2333 | 1497 | 1106 | 1.58 |
| 1 | 10 | 2266 | 1779 | 926 | 1524 | 1.09 |
| 1 | 12 | 1518 | 1551 | 728 | 1288 | 0.98 |
| 1 | 13 | 1809 | 1650 | 1142 | 1423 | 1.08 |
| 1 | 14 | 1539 | 856 | 791 | 929 | 1.14 |
| 1 | 15 | 1851 | 1149 | 925 | 1275 | 1.03 |
| 1 | 16 | 1594 | 1487 | 752 | 885 | 1.44 |
| 1 | 20 | 2507 | 2065 | 1723 | 1596 | 1.31 |
| 1 | 25 | 2511 | 2107 | 936 | 1071 | 1.73 |
| 1 | 30 | 402 | 827 | 486 | 591 | 0.97 |
| 2 | 7 | 2160 | 2715 | 2103 | 1109 | 2.10 |
| 2 | 8 | 775 | 1746 | 1184 | 259 | 4.77 |
| 2 | 9 | 710 | 1885 | 1873 | 609 | 2.45 |
| 2 | 13 | 4771 | 8164 | 6433 | 1071 | 6.03 |
| 2 | 15 | 4233 | 5462 | 3571 | 1610 | 2.75 |
| 2 | 16 | 2229 | 1494 | 902 | 950 | 1.62 |
| 2 | 16 | 1412 | 1025 | 613 | 573 | 1.77 |
| 2 | 17 | 670 | 707 | 589 | 280 | 2.34 |
| 2 | 17 | 4206 | 5207 | 4719 | 2025 | 2.33 |
| 2 | 19 | 1858 | 2631 | 2262 | 1170 | 1.92 |
| 2 | 19 | 2080 | 2762 | 1835 | 591 | 3.76 |
| 2 | 19 | 1427 | 1005 | 483 | 458 | 2.12 |
| 2 | 22 | 1807 | 1973 | 2260 | 776 | 2.59 |
| 2 | 23 | 2109 | 1281 | 951 | 1116 | 1.30 |
| 3 | 9 | 1869 | 3983 | 1425 | 920 | 2.64 |
| 3 | 11 | 2634 | 1714 | 906 | 885 | 1.98 |
| 3 | 13 | 1211 | 1138 | 440 | 411 | 2.26 |
| 3 | 16 | 1456 | 2186 | 1098 | 729 | 2.17 |
| 3 | 18 | 3639 | 2042 | 1186 | 1498 | 1.53 |
| 3 | 19 | 1361 | 1342 | 490 | 573 | 1.86 |
| 3 | 23 | 1293 | 1062 | 537 | 397 | 2.43 |
| 3 | 23 | 2710 | 2095 | 2084 | 831 | 2.45 |
| 3 | 24 | 1427 | 1309 | 907 | 1095 | 1.11 |
| 3 | 32 | 694 | 935 | 423 | 397 | 1.72 |
| 3 | 34 | 817 | 598 | 236 | 547 | 1.00 |

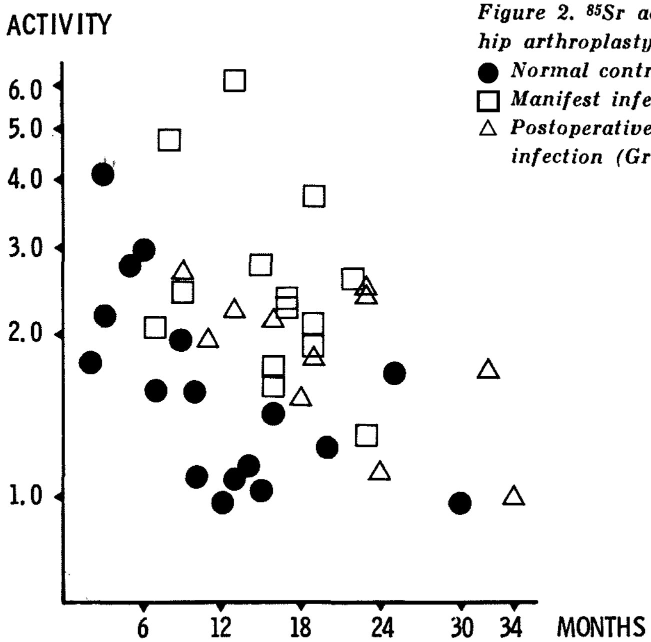



*Figure 2. $^{85}$Sr activity following total hip arthroplasty.*
● *Normal controls (Group 1)*
□ *Manifest infection (Group 2)*
△ *Postoperative pain but no manifest infection (Group 3)*

*arthroplasties (Group 2)* had generally higher activities. Thus 12 of the 14 infected arthroplasties had up to six times higher activities than control cases measured at corresponding postoperative intervals. The difference between control and infected arthroplasties became increasingly apparent with time following operation; the difference between the 11 infected and 8 control arthroplasties, measured 12 months or more postoperatively was significant ($P < 0.01$).

The activities as defined here represented mean values over the entire endoprosthesis area, whereas the scan gave separate values over the different components of the endoprosthesis. The scan thus permitted distinction between those infected arthroplasties in which both components were involved (Figure 4) and those in which only the femoral (Figure 7) or the acetabular component (Figure 8) were involved in the infectious process.

In the *painful arthroplasties without manifest evidence of infection* (Group 3) the activities were significantly higher than in the normal group ($P < 0.05$) but in general were not different from those of the infected group. However, in two of these cases a non-infectious process of periarticular bone formation was very probably a cause both of clinical symptoms (stiffness) and the high activity observed at 9 and

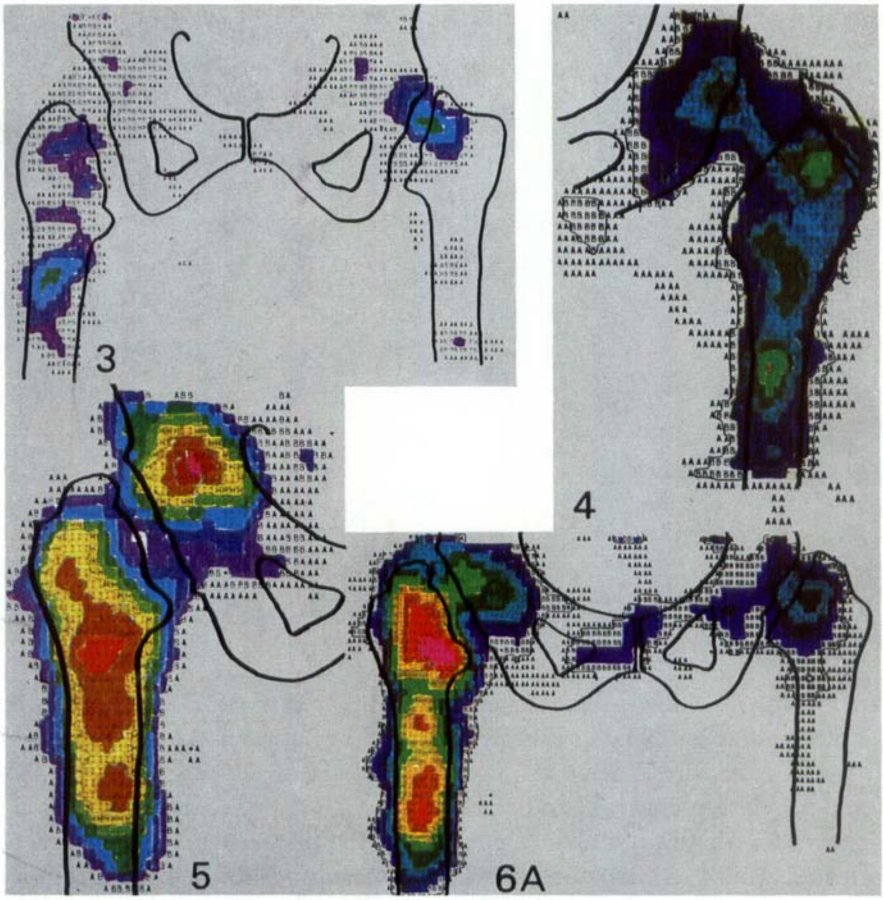



*Figure 3. $^{85}Sr$ radionuclide scintimetry in uncomplicated total hip arthroplasty. Satisfactory clinical results after bilateral arthroplasty. The scan shown here was performed 5 (right) and 9 (left) months postoperatively. Dark blue and dark rose represent uptakes of 6–7 and 40–44 respectively counts/increment of 6 × 6 mm (see Figure 9 b). Intermediate colours represent stepwise additions of 3–4 counts/increment. The warmer the colour the higher the uptake.*

*Figure 4. $^{85}Sr$ radionuclide scintimetry in infected total hip arthroplasty involving both components.*
*Because of postoperative infection with sinus formation both components of the endoprosthesis were removed 19 months postoperatively. At operation both components and the cement were loose and surrounded by plus-like fluid. Culture has not yet identified any microorganisms.*
*The scan shown here was obtained a few days before removal of the endoprosthesis. Note high scintimetry values both over the acetabulum and over the proximal femur corresponding to both components of the endoprosthesis.*

*Figure 5. $^{85}$Sr radionuclide scintimetry in hip arthroplasty with late infection involving both components.*
*Satisfactory result for 12 months postoperatively but then increasing pain, ESR 50–60 mm/h and radiolucency surrounding the prosthesis. Scintimetry was performed 17 months postoperatively. Note very high values over both the femoral and the acetabular components and low values in the space between pelvis and femur.*

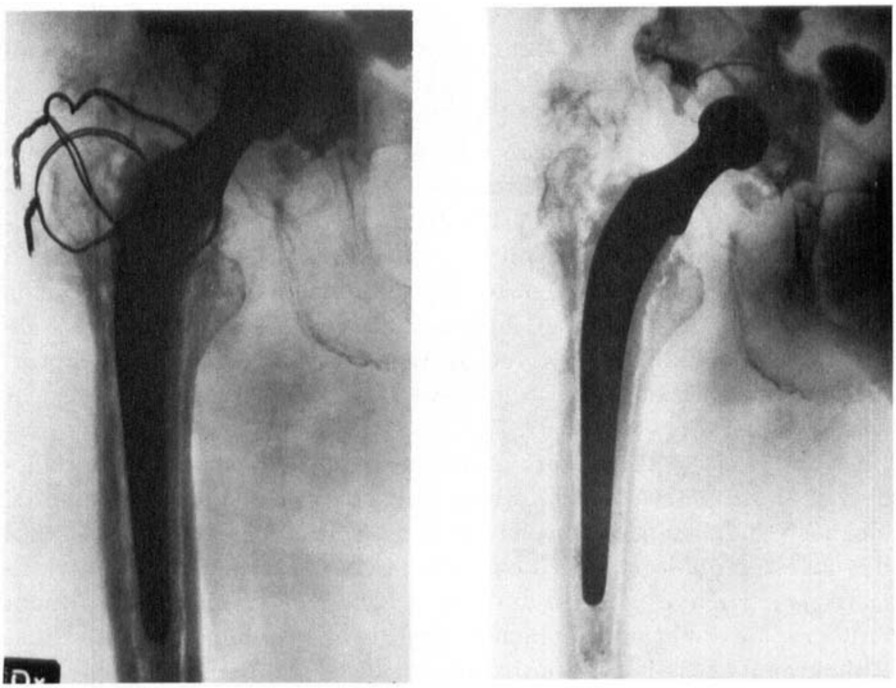


*Figure 6. $^{85}$Sr radionuclide scintimetry in patient with one uncomplicated and one infected arthroplasty.*
*Satisfactory postoperative result in* left hip. *Scintimetry (A) was performed 25 months postoperatively. Note moderate values over proximal femur and low values over the rest of the femur and acetabulum.*
*Because of pain in the lateral aspect of the* right hip *wires were removed. Increasing ESR and progressive radiolucency with irregular borders around the femoral component (B) indicated an infection and the hip was explored 13 months postoperatively. The femoral component and its cement were loose and surrounded by granulation tissue with pus-like fluid, which grew out anaerobic microorganisms, not yet typed. The prosthesis could easily be lifted out. The acetabular component was partly surrounded by the same granulation tissue but appeared stable. It was concluded that no definite infection could be confirmed here.*
*Scintimetry (A) was performed immediately before the endoprosthesis was removed. Note very high values over the entire femoral prosthesis and moderate values over the acetabular region.*

32 months, respectively. Especially in the 9-month case (Figure 9) the scan showed localized high values in the region between the acetabular and the femoral components, and in both cases the radiogram revealed periarticular bone formation exactly corresponding to the scan.

## DISCUSSION

The results of this preliminary investigation show that $^{85}Sr$ radionuclide scintimetry can make a clear-cut distinction between normal and infected arthroplasties at a postoperative interval of 9–10 months or longer. Furthermore, the results obtained in Group 3 strongly suggest that, in agreement with studies of other types of infectious conditions, this distinction can be made even before radiographic abnormalities have become obvious; in view of Charnley's (1972) observation it is highly probable that some of the patients in Group 3 will develop manifest infection. However, infection was not the only cause of abnormally high scintimetry values in this study: periarticular bone formation, non-infectious in origin, was the cause of high values in at least two patients (Figure 9).

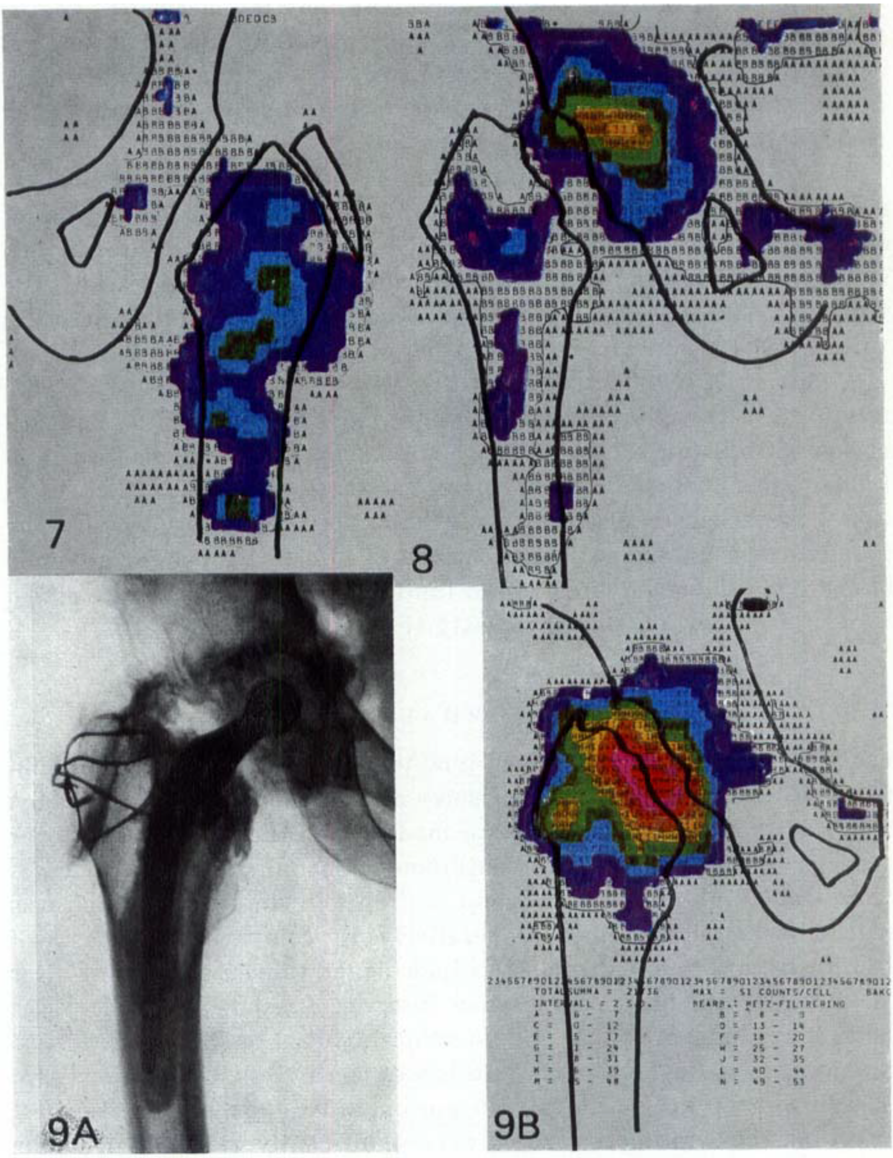
On the basis of the results presented here, it is obvious that radionuclide scintimetry should have an important place in the differential diagnosis of postoperative pain in total arthroplasties. In this sense this investigation confirms the general dictum that radionuclide scintimetry is particularly useful in cases of bone and/or joint pain without radiographic abnormality (Bauer 1968). However, the observation that it took as long as 9–10 months until a distinction could be made between normal and infected arthroplasties decreases the potential usefulness of the method. Further development of the methods used here could shorten this period of ambiguity. First, the number of normal controls should be sufficiently large to permit identification of statistically valid confidence limits. Second, the cause of variations within the group of normals should be identified; periarticular bone formation is one example. Third, we deal here with a problem that differs in principle from the problem of identifying radiographically silent processes in normal bone, for example cancer metastases or haematogenous osteomyelitis. Rather, the problem here is to identify a pathologic process in bone which is already involved in a highly active metabolic process, *viz.* healing following osteotomy, reaming, introduction of acrylic cement and the components of the endoprosthesis, changes in weight-bearing characteristics of the bone stock, etc. Inasmuch as radionuclide scintimetry values represent the first derivative of the radiographic image (Figure 22 in Bauer 1968), perhaps the second derivative, i.e. changes in the scintimetry values, would provide additional information. We are at present testing this hypothesis by doing repeat scintimetries on a prospective basis.

As compared to other applications of radionuclide scintimetry, especially as regards the appendicular skeleton, the scintimetry values obtained in cases of hip arthroplasty are difficult to evaluate; in this study the hip values have been expressed in terms of the lowest knee value (Danielsson et al. 1963), but it may prove better to relate hip values to total body retention (Cameron 1969).

At any rate, we conclude from this study that diagnosis and hence treatment of infection following total hip arthroplasty can be achieved earlier if radionuclide scintimetry is added to clinical, chemical and radiographic methods. Furthermore, causes of pain other than infection may perhaps be excluded with the aid of scintimetry. Finally, the possibility of making an early diagnosis of infection involving only one of the two components may aid in limiting a surgical procedure aimed at eventually saving the arthroplasty (Figure 8).

## SUMMARY

Forty-two cases of the Charnley type total hip arthroplasty were subjected to $^{85}Sr$ radionuclide scintimetry at 2–34 months postoperatively. Scintimetry was performed in two modes, with the counter fixed over predetermined positions and continuously scanning. In normal cases an initially high uptake was found to drop to a stable level which was reached some 10 months postoperatively. By comparison, 14 cases of manifestly infected arthroplasties had higher values, significant after the initial 12-month postoperative interval. In some of these cases scintimetry suggested that the infection involved only one of the two components of the arthroplasty; this was confirmed at operation. Also in a third group of 11 cases with postoperative pain but no manifest infection, the scintimetry values were significantly higher than in the normals. In two of these cases the scintimetry pattern corresponded to radiographic evidence of periarticular bone formation as a cause of postoperative pain and stiffness. In at least some of the others it is probable that the elevated scintimetry values signified infection which will only later become manifest radiographically. It is concluded that radionuclide scintimetry is a useful adjunct in the differential diagnosis




*For colour code, see caption Figure 3.*

*Figure 7. $^{85}$Sr radionuclide scintimetry in total hip arthroplasty with postoperative infection involving only the femoral component.*
*Because of sinus formation and other signs of infection the endoprosthesis was removed 8 months postoperatively. The femoral component and its cement were loose and surrounded by a thick granulation tissue including a yellowish fluid which grew out anaerobic microorganisms, not yet typed. The acetabular component, however, was completely stable and it could be removed only with great difficulty; there were no signs of infection under the cement.*
*Scintimetry was performed immediately before the endoprosthesis was removed. Note high values over the proximal femur and low values over the acetabulum, corresponding to the operative finding of infection involving only the femoral component.*

*Figure 8. $^{85}$Sr radionuclide scintimetry in total hip arthroplasty with infection involving only the acetabular component.*
*Because of pain, increasing ESR and radiographic signs of infection the right hip was explored 17 months postoperatively. The acetabular component with its cement was completely loose and a thick granulation tissue with pus-like fluid grew out anaerobic microorganisms, not yet typed. In contrast to the acetabular component, the femoral component was completely stable without macroscopic signs of infection. The femoral component was therefore not removed and continuous flow drainage was established. After intensive treatment with antibiotics a new acetabular cup has been inserted. 2 months postoperatively the patient is painfree and there are no signs of infection.*
*Scintimetry was performed immediately before the hip was explored. Note high values almost exclusively over the acetabulum.*

*Figure 9. $^{85}$Sr radionuclide scintimetry in total hip arthroplasty with periarticular bone formation.*
*Gradually developing postoperative pain and stiffness but normal ESR. Seven months postoperatively, radiography (A) showed periarticular bone formation and scintimetry (B) markedly high values in the region between the acetabulum and the proximal femur.*

---

of postoperative pain in total arthroplasties, in particular that infection may be diagnosed and treated earlier with the aid of this method, and that identification of infection involving only one of the two components of the endoprosthesis may aid in attempts at surgically saving the arthroplasty.

## REFERENCES

Bauer, G. C. H. & Wendeberg, B. (1959) External counting of Ca-47 and Sr-85 in studies of localized skeletal lesions in man. *J. Bone Jt Surg.* **41**-B, 558.

Bauer, G. C. H. (1968) The use of radionuclides in orthopaedics. Part IV. Radionuclide scintimetry of the skeleton. *J. Bone Jt Surg.* **50**-A, 1681.

Bergström, B., Lidgren, L. & Lindberg, L. (1973) Radiographic abnormalities caused by postoperative infection following total hip arthroplasty. *Clin. Orthop.* (in press).

Cameron, R. B. (1969) $^{85}$Sr scintimetry in non-traumatic necrosis of the femoral head. *Clin Orthop.* **65**, 243.

Charnley, J. (1972) Postoperative infection after total hip replacement with special reference to air contamination in the operating room. *Clin. Orthop.* **87**, 167.

Danielsson, L. G., Dymling, J.-F. & Heripret, G. (1963) Coxarthrosis in man studied with external counting of $^{85}$ Sr and $^{47}$Ca. *Clin. Orthop.* **31**, 184.

Dreyer, J. & Georgi, P. (1972) Möglichkeiten und Grenzen der Skelett-Szintigraphie für die Orthopädie. *Aktuelle Orthopädie,* ed. by Cotta, Horst, p. 21. G. Thieme Verlag, Stuttgart.

Dymling, J.-F. & Wendeberg, B. (1965) External counting of $^{85}$Sr and $^{47}$Ca in localized bone infection. *Acta orthop. scand.* **36**, 8.

Felländer, M. & Lindberg, L. (1966) Clinical use of radiostrontium in evaluation of spondylitis. *J. Bone Jt Surg.* **48**-A, 1585.

Groher, W., Venohr, H. & Klems, H. (1972) Szintigraphische Verlaufskontrollen nach alloplastischem Hüftgelenkersatz. Exhibit at "59. Tagung der Deutschen Gesellschaft für Orthopädie und Traumatologie", Berlin.

Gustafsson, T., Möller, T. & Naversten, Y. (1971) Experiences of computer-aided scintigraphy in clinical routine. Paper presented at the Second European Meeting on Data-handling and Image-Processing in Scintigraphy, Hannover. In press.

Möller, T., Gustafsson, T. & Naversten, Y. (1973) Experiences of computer-evaluation of thyroid-scans in clinical routine. Medical Radioisotope Scintigraphy, Vienna, IAEA. In press.

Naversten, Y., Gustafsson, T. & Möller, T. (1972) A system for processing scintigraphic images and evaluation of organ-parameters. Lecture delivered at the International Conference on Medical Physics, including medical engineering, Gothenburg, Sweden, July 30–August 4.

Nöh, E. (1972) Szintigraphische Untersuchungen bei Totalprothesenoperierten. Exhibit at "59. Tagung der Deutschen Gesellschaft für Orthopädie und Traumatologie", Berlin.

Correspondence to:

Lars-Olof Sjöstrand
Dept. Orthop. Surgery
Lund University Hospital
S-221 85 Lund, Sweden