Quantitative bone scanning after asymptomatic Charnley arthroplasty

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To establish the normal pattern of postoperative tracer uptake we performed 73 ^{99m}technetium methylene diphosphonate scans following primary Charnley hip replacements for arthrosis in 68 patients without clinical, hematological and radiographic complications. The patients were divided into 7 subgroups according to the period, 6–24 months, between surgery and scan. There were 10–12 patients in each subgroup. A high-resolution gamma camera with a large field of view was used. Ratios of uptake in each of 10 peri-prosthetic zones to normal bone were calculated.

Femoral uptake was found to decrease in linear fashion from 6 to 12 months after surgery. Thereafter the uptake remained unaltered at levels nearly twice the normal ones in the greater trochanter and nearly 1.5 times in the lesser trochanter, returning to almost normal levels in other zones. Acetabular uptake remained elevated throughout.

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Radionuclide imaging may be used to differentiate septic from aseptic loosening when preliminary ^{99m}Tc-MDP scans show increased uptake. However, even after uncomplicated hip replacements, there is increased tracer uptake around the prosthesis (Bauer et al. 1973). The increased uptake is reported to last for 6–24 months (Weiss et al. 1979, Williamson et al. 1979, Browett and Ostrowski 1980, de Rossi and Focacci 1983, Utz et al. 1986, Bridle et al. 1989). Prosthetic loosening and infection can also increase radionuclide activity around the prosthesis which must be distinguished from the normal pattern.

Therefore, we quantified the ^{99m}Tc-MDP uptake in the various peri-prosthetic zones during the 6–24-month period after uncomplicated Charnley arthroplasty to establish the pattern of uptake in different zones.

Patients and methods

From hospital records we selected patients who in 1988–1990 underwent primary Charnley hip replacement for arthrosis through a posterior or direct lateral approach without trochanteric osteotomy, had an uneventful post-operative recovery, were asymptomatic at regular reviews, and were found not to have any clinical or radiographic complications in a minimum follow-up of 2 years. Patients were excluded from the study if bone-grafting of acetabulum or femur had been carried out at the time of arthroplasty and if inadvertent fracture had occurred. Patients with Paget's disease, myeloma, metastases, marrow disorders or metabolic bone disease were excluded.

All the patients were assessed clinically by two of the authors (ABM or RCT) prior to scanning, and a Harris (1969) score was obtained; patients with any symptoms attributable to the prosthetic hip were excluded. Patients were also excluded if at the time of the scan their ESR exceeded 35 mm, WBC count was over 11×10^9 cells/L, or if serial anteroposterior and lateral radiographs showed any signs of loosening (Tehranzadeh et al. 1988).

Informed consent was obtained in all cases. Consenting patients were divided into 7 groups based on the interval from operation to scanning, so that patients in each group were scanned at 6, 9, 12, 15, 18, 21, or 24 months. All scans were done within a week of the specified post-operative interval.

All scans were performed in the Department of Nuclear Medicine, Colchester General Hospital. A Siemens Orbiter camera with a large field of view and 75 photomultiplier tubes was used along with a high-resolution parallel-hole collimator. This was attached to a Siemens Dot Console and Microdot

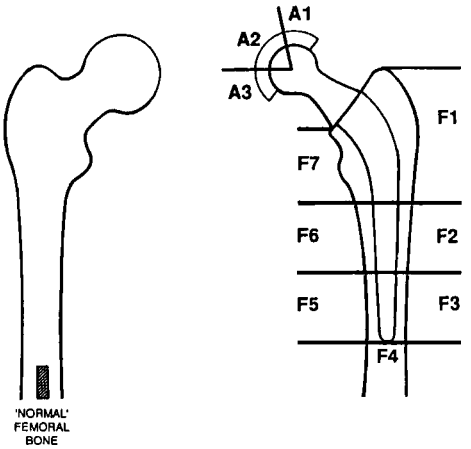

Figure 1. The 11 zones from where uptake was obtained.

Imager for analogue images and linked to a Siemens Microdelta computer for storage and data processing. 500 MBq of ^{99m}Tc-MDP (Amerscan Medronate II kit; Radiochemical Centre, Amersham, England) were injected intravenously. Anterior and posterior images of the pelvis and proximal femora were taken approximately 2.5 h after injection. The image acquisition time was 5 min for each view. Analogue images were obtained on x-ray films. Images were stored on computer for data processing on a 256 × 256 matrix. These were then smoothed once (9-point smooth) prior to data processing.

A software program was designed to demarcate 11 regions of interest on the scan (Figure 1): 3 acetabular peri-prosthetic zones (DeLee and Charnley 1976) designated A1–3; 7 femoral peri-prosthetic zones (Gruen et al. 1979) F1–7; and one area over the isthmus of the contralateral femur taken to represent the normal bone value. The maximum pixel value of each area was recorded. In each periprosthetic zone the ratio of uptake to that of normal bone was calculated separately for the anterior and posterior images. The uptake ratios of anterior and posterior images were then averaged and used for further calculations. The relationship between these values of uptake ratio in the different zones and the time elapsed since operation was then analyzed. All readings were obtained by SR who was unaware of the time interval between operation and scans. A statistician was consulted for analysis and interpretation of the data. An IBM PC computer and a Magnavox Professional PC computer were used, and the results were stored in Minitab release 7.2 statistical analysis package and Excel version 2.1d software.

The values of uptake ratio in each zone (e.g., A1) for all patients in a group (e.g., 6 months postoperatively) were averaged. This was done for each acetabular and femoral zone, and the mean values were plotted against time. In addition, analysis of variance and regression of uptake with time were determined using the values of uptake ratio in each zone in all 68 patients. Again, this was carried out in all acetabular and femoral zones.

Of 100 patients considered as possible candidates for inclusion in the study, 79 patients underwent ^{99m}Tc-MDP scans after being found to be without complications after clinical examination, laboratory tests, and radiography. 11 scans were technically inadequate (from contamination of undergarments due to incontinence of urine) and these patients were excluded from the study.

The scans of 73 Charnley total hip replacements in 68 patients were studied. The patients were 73 (60–86) years old. There were 36 females. 5 patients had bilateral hip replacements. Cement was pressurized by digital means or by using a syringe; bone blocks or plastic cement restrictors were used.

The Harris score averaged 78 (standard deviation 6.5), reflecting the uncomplicated situation in these patients.

Results

Femoral uptake decreased in near-linear fashion in all zones from 6 to 12 months after surgery (Table 1). Analysis of variance showed a linear decrease in uptake from 6 to 12 months ($P < 0.05$ in F1 and F7 zones and P 0.06 in F4), with essentially no change in uptake between patients scanned from 12 to 24 months. While P-values in the other zones were not significant, they did not contradict those in zones F1, F4 and F7. The coefficients of the regression equation were all consistently negative in all femoral zones from 6 to 12 months, confirming the decrease in uptake; from 12 to 24 months they were nearer to zero.

Acetabular uptake decreased between patients scanned at 6 through 12 months in all zones. This trend was confirmed by the negative coefficients of the regression equation. However, on analysis of variance the P-values were not found to be significant. The slight increase in uptake from 12 to 24 months was not borne out by analysis of variance.

Thus, acetabular uptake was found to remain elevated, even up to 24 months, at levels nearly twice those of normal bone. In the femur, the trochanteric regions, and to a lesser extent the prosthetic tip region, showed a drop in uptake between patients scanned at 6 through 12 months. In the other zones

Table 1. Mean values of uptake ratio zonewise for each group of patients

	Acetabulum			Femur						
Months	A1	A2	A3	F1	F2	F3	F4	F5	F6	F7
6	2.29	2.10	1.90	2.29	1.19	1.45	1.44	1.28	1.31	1.78
9	2.01	2.19	2.09	2.07	1.19	1.29	1.27	1.26	1.23	1.54
12	1.98	1.89	1.73	1.75	1.11	1.25	1.16	1.20	1.18	1.46
15	1.87	1.93	1.83	1.73	1.09	1.18	1.19	1.20	1.15	1.45
18	2.03	1.93	1.83	1.98	1.25	1.19	1.18	1.23	1.17	1.45
21	1.96	1.92	1.76	1.84	1.08	1.19	1.13	1.15	1.14	1.49
24	2.06	2.15	1.99	1.97	1.18	1.26	1.14	1.25	1.24	1.51

Table 2. Months taken for ^{99m}Tc-MDP uptake to return to normal after uncomplicated hip replacement according to different studies

Author	Acetabulum	Femur
Weiss et al.	6–8	6–8
Williamson et al.	6	6
Browett and Ostrowski	16–24	12
de Rossi and Focacci	8	8
Utz et al.	6–12[a]	6–12[b]
Bridle et al.	12–60[c]	12–24

[a]Persistent activity in 10 percent, [b]20 percent, and [c]35–60 percent

Table 3. Value of sequential imaging with gallium and indium-labeled WBCs in the diagnosis of painful hip prostheses (percent)

Tracer / Author	Sensitivity	Specificity	Accuracy
Tc-Gallium			
Lyons et al.	67	100	77
Aliabadi et al.	37	100	–
Tehranzadeh et al.	80	100	90
Merkel et al.	66	81	77
McKillop et al.	83	78	–
Indium			
McKillop et al.	50	100	–
Mulamba et al.	92	100	94
Pring et al.	100	66	80
Johnson et al.	100	50	65
Johnson et al.[a]	88	95	93
Magnuson et al.	88	73	81
Wukich et al.[a]	85	85	85
Wukich et al.	100	45	65
Cuckler et al.	60	73	70

[a] + Tc-MDP

there were similar though smaller changes. Beyond 12 months, the uptake remained almost unaltered in all zones. Uptake remained at levels nearly twice that of normal femoral bone in the greater trochanter, nearly 1.5 times in the lesser trochanter, but fell to nearly normal levels in the remaining areas.

Discussion

There is considerable variation in the literature as regards uptake of tracers after asymptomatic and uncomplicated hip replacements (Table 2). There is also lack of agreement on the interpretation of tracer activity after sequential imaging with gallium or indium-labeled WBCs in complicated cases (Table 3).

We feel that there are several possible reasons for the diversity of opinion with regard to ^{99m}Tc-MDP patterns after asymptomatic THR. The type of arthritis was not specified in most studies; activity patterns may be different in patients with rheumatoid arthritis (Rosenthall et al. 1979, Magnuson et al. 1988). We included only arthrosis patients. The type of prosthesis can alter the activity pattern, and it is known that uncemented femoral stems have a different appearance (Lifeso et al. 1991); most reports did not specify this detail, nor the operative approaches and methods of cementing used, all of which can alter uptake, particularly if trochanteric osteotomy is performed (Weiss et al. 1979).

Only one study (Browett and Ostrowski 1980) used both visual and quantitative methods of analysis in all the cases; however, the authors used the iliac crest for comparison. This region, because of its spatial asymmetry, shows various uptakes on the anterior and posterior images and can thus be misleading. The remaining reports used purely visual means of determining uptake (Utz et al. 1986). Moreover, normal hip and sacroiliac joints are known to show an increased uptake (Kirchner and Simon 1981).

We prefer to use the isthmic region of the opposite femur for comparison. We feel that the accuracy of our method is enhanced by averaging the uptake ratios in anterior and posterior views and determining uptake zonewise in the acetabulum and femur. Our method also eliminates from measurements the region between the cup and proximal femur, where heterotopic ossification most commonly occurs. Increased tracer activity due to heterotopic ossification

may be confused with that due to component loosening on visual analysis (Gelman et al. 1978).

In the acetabulum, persistent tracer activity, based on visual analysis, has also been noted by Bridle et al. (1989). Whether this persistent tracer activity represents peri-articular biological activity, which is normally more than on the femoral side or bone reaction or is simply a very sensitive indicator of true loosening from the very beginning, remains as yet undefined. Thus, the value of radionuclide imaging for detecting acetabular complications is questionable (Gelman et al. 1978, Weiss et al. 1979, Bridle et al. 1989). In contrast to this, uptake in the trochanteric zones drops to 1.5–2 times normal femoral levels at 24 months. Uptake in these zones, even in normal scans of the contralateral unreplaced femur, exceeds 1.0. This is corroborated by the finding that uptake ratios return to those levels rather than to 1.0.

Studies based on visual analysis of uptake show very conflicting trends; we suggest that quantitative analysis allows a more accurate method of assessing activity pattern (Bauer et al. 1973). Any deviation from the trend shown in this study may help exclude a normal post-operative course. Quantitative serial uptake values may be even more meaningful in the evaluation of a painful prosthesis.

The use of visual methods to compare ^{99m}Tc MDP uptake with gallium (which is less specific and seldom used) or indium-labeled WBCs to determine whether or not there is congruence between tracer patterns is also prone to error—as is perhaps reflected in the wide variation in reported accuracy and usefulness. We suggest that if sequential scanning with gallium or indium is employed after initial technetium MDP imaging, then quantification of uptake, in the manner described in this study, for comparison of congruence or lack of it would provide more objective and reliable data. This would enhance further the value of radionuclide imaging in the patient with a painful prosthesis.

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