The Acetabulum: A Prospective Study of Three-Phase Bone and Indium White Blood Cell Scintigraphy Following Porous-Coated Hip Arthroplasty

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Although few studies address the use of three-phase bone scanning (TPBS) and indium-111-labeled white blood cell scintigraphy (^{111}In-WBC) in hip arthroplasty utilizing a porous-coated prosthesis, the literature suggests that scintigraphic patterns in the uncomplicated patient may differ form that seen with the cemented prosthesis. In an attempt to determine the scintigraphic natural history, 25 uncomplicated porous-coated hip arthroplasties in 21 patients were prospectively studied with serial TPBS and ^{111}In-WBC at ~7 days, and 3, 6, 12, 18, and 24 mo postoperatively. This report deals with findings related to the acetabulum. All 25 prostheses (144 of 144 scans) demonstrated increased uptake on the bone-phase images. Although this activity decreased with time, 76% had persistent uptake at 24 mo. Twenty-three of 25 prostheses (126 of 140 scans) showed increased uptake on ^{111}In-WBC scintigraphy, invariably decreasing with time, but with 37% having significant uptake at 24 mo. Scintigraphic patterns in the uncomplicated porous-coated hip arthroplasty patient appear to differ from patterns described in cemented prostheses.

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Although the complications of prosthetic loosening and infection are uncommon following total-hip arthroplasty, the definitive diagnosis of these entities may present a considerable challenge to the clinician. Scintigraphic studies including bone scanning (*1*), gallium scanning (*2*), radionuclide arthrography (*3*), and indium-111-labeled white blood cell (^{111}In-WBC) studies (*4*) may be helpful in the evaluation of a suspected complication. The utilization of these studies in the evaluation of complicated and uncomplicated cemented hip prostheses has been well described (*1–12*). With the development of porous-coated prostheses implanted without cement, the method of prosthetic fixation has changed (*13*). The porous coating of the prosthesis allows ingrowth of bone and fibrous tissue into the prosthesis surface itself. This might be expected to cause increased uptake of bone-avid isotopes, allowing an altered scintigraphic appearance unrelated to the suspected complication. Unless these scintigraphic changes are known, errors in interpretation of radionuclide studies could occur.

In an attempt to establish the natural history of scintigraphic changes following uncomplicated porous-coated hip arthroplasty, patients were prospectively studied using serial three-phase bone scans (TPBS) and ^{111}In-WBC scintigraphy. The data, as it relates to the tip of the prosthesis, has been previously published (*14*). This report describes the scintigraphic findings related to the acetabulum in 25 prostheses so studied. The scintigraphic findings related to the trochanters will be reported separately.

MATERIALS AND METHODS

The methods have been previously described in detail (*14*) and will only be briefly reviewed here. From January through October 1985, a prospective study was performed on patients undergoing total-hip arthroplasty utilizing an uncemented porous-coated prosthetic device (PCA Total Hip System, Howmedica, Rutherford, New Jersey). Informed consent was obtained. All patients were studied with serial clinical evaluations, radiographs, TPBS, and (^{111}In-WBC) scintigraphy. Serial clinical evaluations, including Harris hip ratings (*15*), were performed on all patients. No patient demonstrated any clinical evidence of infection and none had pain requiring the use of medication. No patient had any radiographic evidence of loosening during the study. The radionuclide studies were scheduled at 7 days and at 3, 6, 12, 18, and 24 mo postoperatively. The acetabulum, the trochanters, and the prosthetic tip were each evaluated on TPBS and ^{111}In-WBC. This paper

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will discuss the scintigraphic findings related to the acetabulum of the porous-coated prosthesis.

Imaging Technique

On the day of the study, blood was drawn and the patient's white blood cells were labeled with ^{111}In-oxine while the TPBS was being performed (*14*). The flow, blood-pool, and bone-phase images were obtained in a standard fashion using a 20% window centered about the 140 keV peak. Following completion of the TPBS, the patient's ^{111}In-labeled WBC were injected intravenously. Images were acquired using a 20% window centered about the 247 keV peak and a 15% window asymmetrically placed about the 172 keV peak. If a second image was required to view the entire prosthesis it was obtained for the same length of time as the first image.

Interpretive Criteria

All images were evaluated by one of the authors according to the following criteria. For blood flow and blood-pool determinations background was defined as that activity occurring in the soft tissues of a similar region in the contralateral hip. The peak activity in the contralateral iliac vessel was used as a reference point. Blood flow or blood pool was grade 0 when no increased activity above background was detected, grade 1+ when activity was present greater than background but less than the reference point, grade 2+ when activity was equal to the reference point, and grade 3+ when activity was greater than the reference point.

Flow. Blood flow was evaluated in the region of the acetabulum semi-arbitrarily from injection to 8 sec after peak iliac vessel activity using the stated criteria.

Blood Pool. Blood-pool activity was evaluated in the region of the acetabulum on a image obtained ~5 min after injection using the stated criteria.

Bone and Indium-White Blood Cells. The bone-phase and ^{111}In-WBC images were evaluated for intensity of uptake at the acetabulum. Background was defined as that uptake occurring in the contralateral femoral shaft or, in patients with bilateral prostheses, in the ipsilateral femoral shaft well distal to the prosthesis tip. The ipsilateral iliac crest was used as the reference point. Grade 0 was assigned when there was no increased uptake above background, 1+ when uptake was above background but less than the reference point, 2+ when uptake was equal to the reference point, 3+ when uptake was greater than the reference point, and 4+ when activity was significantly greater than the reference point (Figs 1 and 2).

Analysis

No additional analysis was performed on either flow or blood pool. Following study completion, each individual prosthesis was evaluated serially to detect any trend in changing intensity which might have occurred over time. Images were also analyzed for the pattern of uptake, defined as the size and configuration of activity. In addition, congruence of intensity, defined as a comparison of the grade of tracer uptake in the area of interest on the ^{111}In-WBC study relative to the same area of interest on the bone-phase image, was analyzed.

RESULTS

Twenty-five porous-coated hip arthroplasties in 21 consecutive patients were studied. There were 14 males and 7 females with a mean age of 62 (range 39 years to 77 years). Preoperative diagnoses included osteoarthritis in 19 patients, rheumatoid arthritis in one patient, and aseptic necrosis in one patient.

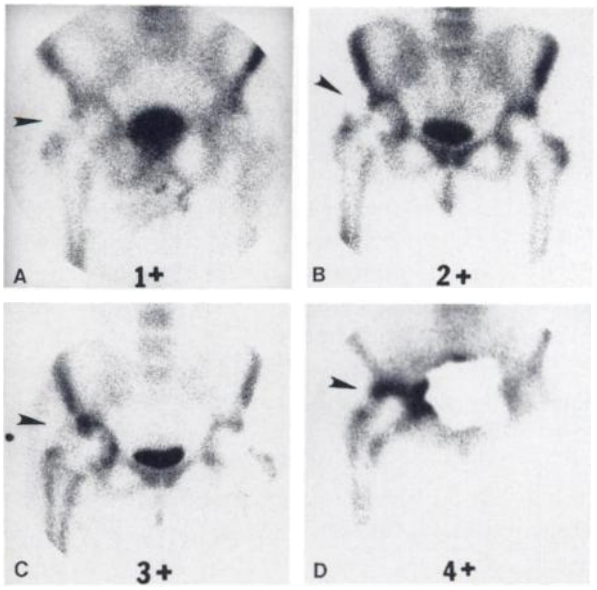

FIGURE 1
Examples of intensity grades 1+ through 4+ at the acetabulum for bone phase images are shown. The arrows indicate the side evaluated.

Flow. Of the 150 scheduled TPBS, 134 flow studies were technically adequate for interpretation. None demonstrated any flow abnormality in the region of the acetabulum.

Blood Pool. Of the 150 scheduled TPBS, 139 studies were technically adequate for interpretation of aceta-

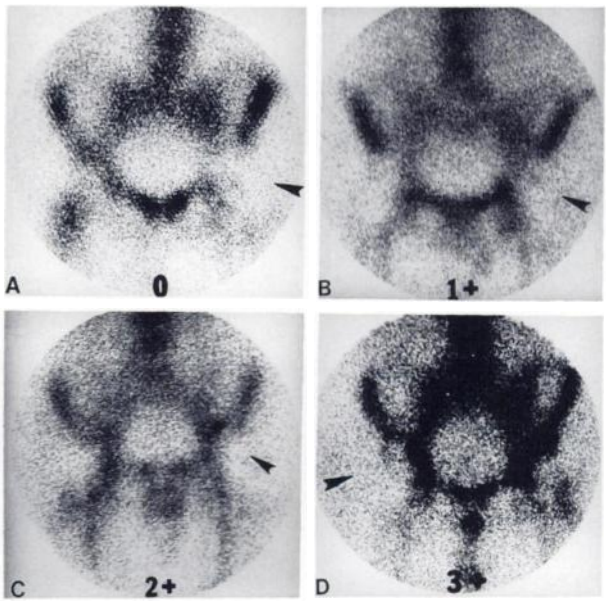

FIGURE 2
Examples of intensity grades 0 through 3+ at the acetabulum for ^{111}In-WBC images are shown, arrows indicating the evaluated side.

bular blood-pool activity. Twenty-two percent (30 of 139 scans) demonstrated increased blood-pool activity. All increased blood-pool activity was confined to the 7-day and 3-mo scans with the exception of a single study showing 1+ blood-pool activity at 18 mo postoperatively.

Bone (Frequency of Uptake). Of the 150 scheduled TPBS, 144 bone-phase images were performed and were adequate for interpretation. Increased acetabular Tc-MDP uptake was present in 100% of prostheses (25 of 25) and in all scans (144 of 144).

Bone (Intensity Grade). Of the 144 usable bone phase images, intensity of uptake was grade 1+ in 12% (17 scans), grade 2+ in 47% (67 scans), grade 3+ in 35% (51 scans), and grade 4+ in 6% (9 scans). When considering the 25 prostheses as a group, intensity of uptake at the acetabulum for each scanning time can be appreciated by reviewing Figure 3.

Bone (Trend in Intensity). The data is shown in Figure 4.

Bone (Pattern of Uptake). Three distinct patterns of Tc-MDP uptake were appreciated. Uniform tracer uptake (pattern I) in the acetabulum was seen in 22% (32 of 144 scans). In 51% (74 of 144 scans) uptake was nonuniform with greater intensity noted at *either* the superior or the inferior aspect of the acetabulum (pattern II). In pattern III, uptake was also nonuniform showing greater intensity of Tc-MDP uptake at *both* the superior and the inferior aspects of the acetabulum in 25% (36 of 144 scans). Two of the 144 scans could not be classified into these patterns (Figure 5).

Indium-111-WBC (Frequency of Uptake). Of the 150 scheduled ^{111}In-WBC studies, 140 were adequate for interpretation of acetabular activity. Of these, 90% (126 scans) showed increased tracer uptake at the acetabulum. Of the 25 prostheses studied, 92% (23 prostheses) demonstrated increased tracer uptake at some time during the 24 mo of the study.

Indium-111-WBC (Intensity Grade). Of the 140 appraisable ^{111}In-WBC scans, the intensity of uptake was grade 0 in 10% (14 scans), 1+ in 41% (58 scans), 2+ in 46% (65 scans), and 3+ in 2% (3 scans). When considering the 25 prostheses as a group, intensity of uptake at the acetabulum for each scanning time can be appreciated by reviewing Figure 6.

Indium-111-WBC (Trend in Intensity). All prostheses exhibited stable or decreasing intensity of activity during the 24 mo of the study.

Indium-111-WBC (Pattern of Uptake). Two distinct patterns of ^{111}In-WBC uptake at the acetabulum, uniform and nonuniform, were appreciated. An example of each pattern is shown in Figure 7. Nonuniform uptake was seen as an area of relative photon deficiency in the central aspect of the acetabulum. In addition, focal areas of increased ^{111}In-WBC activity projecting over the groin and proximal thigh were noted in 37% of scans (53 of 140) and in 60% of prostheses (15 of 25). An example of such activity is shown in Figure 8.

Indium-111-WBC (Congruence of Intensity). Of the 139 usable studies for congruence of intensity, uptake of ^{111}In-WBC was less than Tc-MDP uptake in 64% (89 scans), equal to Tc-MDP uptake in 34% (47 scans), and greater than Tc-MDP uptake in 2% (3 scans).

DISCUSSION

The definitive diagnosis of infection or loosening in the patient with a painful hip prosthesis may be difficult and radionuclide evaluation is often helpful. Radionuclide findings for cemented prostheses have been described for the complications of loosening and infec-

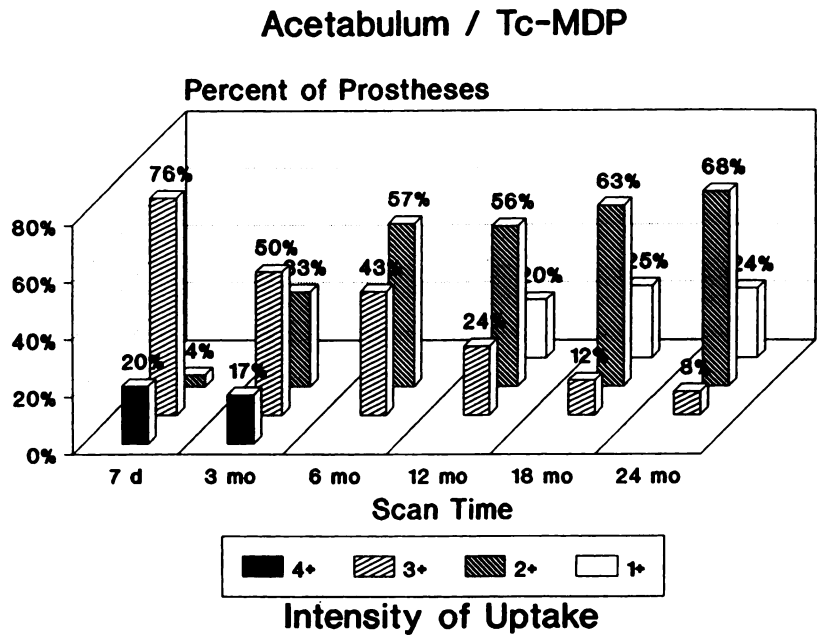

FIGURE 3
Considering the 25 prostheses as a group, the graph shows the percentage of prostheses demonstrating a given intensity of Tc-MDP uptake at the acetabulum at the various scanning times.

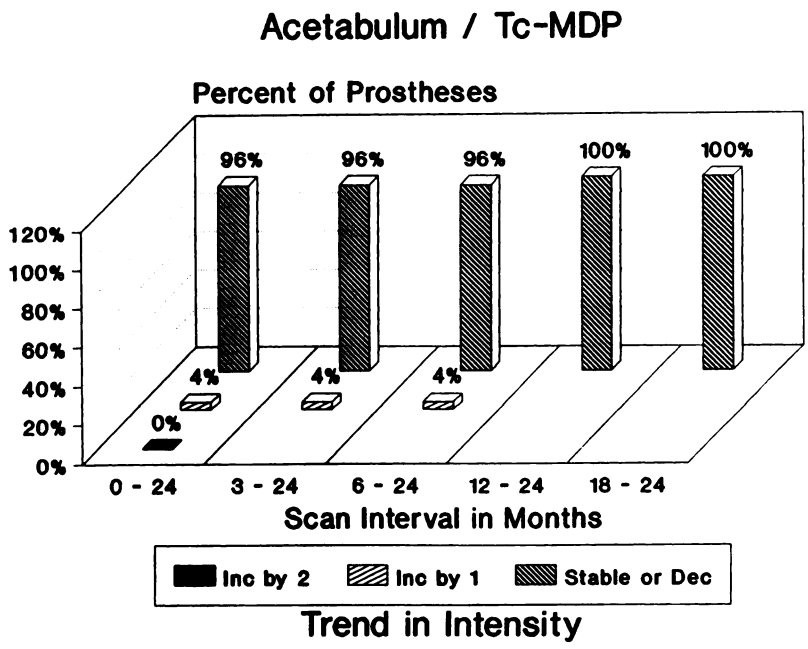

FIGURE 4
The graph shows the percentage of prostheses demonstrating a trend in changing Tc-MDP intensity at the acetabulum for each indicated time interval. For example, during the interval encompassing 3–24 mo postoperatively, 96% of prostheses exhibited stable or decreasing activity, 4% (one prosthesis) showed an increase by one intensity grade, and none demonstrated an increase by two intensity grades.

tion (*1–4, 6–12*), as well as for the uncomplicated patient (*5*). Our focus was a prospective study of scintigraphic findings in uncomplicated patients with porous-coated prostheses. Since the method of fixation is different for the porous-coated prosthesis, the scintigraphic findings in the uncomplicated patient might also be expected to be different. There are few reports in the literature, however, addressing this point.

Amstutz et al. (*16*) reported on 58 patients undergoing 62 hip arthroplasties using a porous-surfaced prosthesis; however, only 11 patients were scanned beyond one year. He reported increased acetabular activity on technetium diphosphonate bone scans out to two years. This represented increased uptake for a longer period of time when compared to his experience with stable cemented components. This activity was believed to be a result of continued remodeling of bone at the bone-prosthesis interface. Schicha et al. (*17*), reporting on 69 porous-coated arthroplasties in 61 uncomplicated patients, found only 9% with increased uptake in the acetabular region at two years. However, not all patients had multiple scans performed during the study interval.

This report of the systematic, prospective evaluation of 25 porous-coated prostheses with Tc-MDP and ^{111}In-WBC scintigraphy is an attempt to better define the natural history of scintigraphic changes in the uncomplicated patient. We believe this data is of value in establishing the "normal" pattern of activity in these patients, thereby providing a standard by which patients with suspected complications of infection and loosening may be compared.

One might have anticipated that increased blood flow and blood-pool activity would be seen in the immediate postoperative TPBS. However, none of the 134 images demonstrated increased blood flow. Although 22% of scans demonstrated increased focal blood-pool activity, this was almost always limited to the first few months postoperatively. This implies that increased blood flow at any time or focal blood-pool activity after three months should raise the suspicion that a complication is present.

Unlike the flow or blood-pool segments of the TPBS, the bone-phase images demonstrated universal tracer uptake. The ubiquitous presence of increased Tc-MDP uptake at the acetabulum at some time during the 24 mo of study (with 76% of prostheses still demonstrating uptake greater than or equal to iliac crest at 2 yrs) implies that the presence or absence of uptake alone is of no clinical value in diagnosing infection or loosening. However, analysis of intensity over time for each indi-

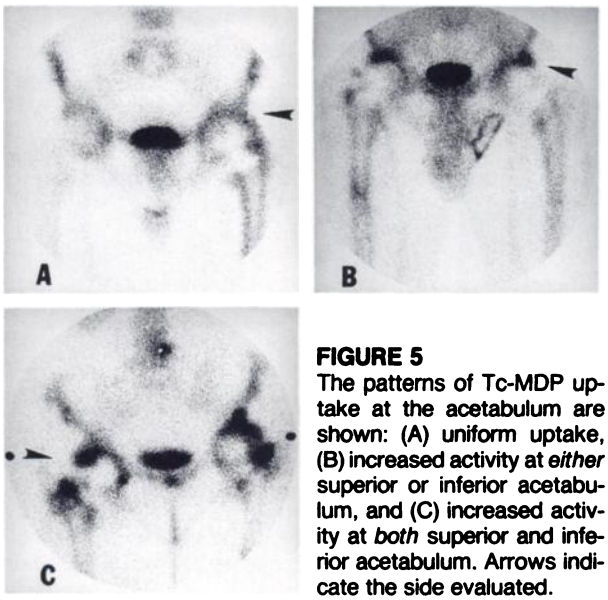

FIGURE 5
The patterns of Tc-MDP uptake at the acetabulum are shown: (A) uniform uptake, (B) increased activity at *either* superior or inferior acetabulum, and (C) increased activity at *both* superior and inferior acetabulum. Arrows indicate the side evaluated.

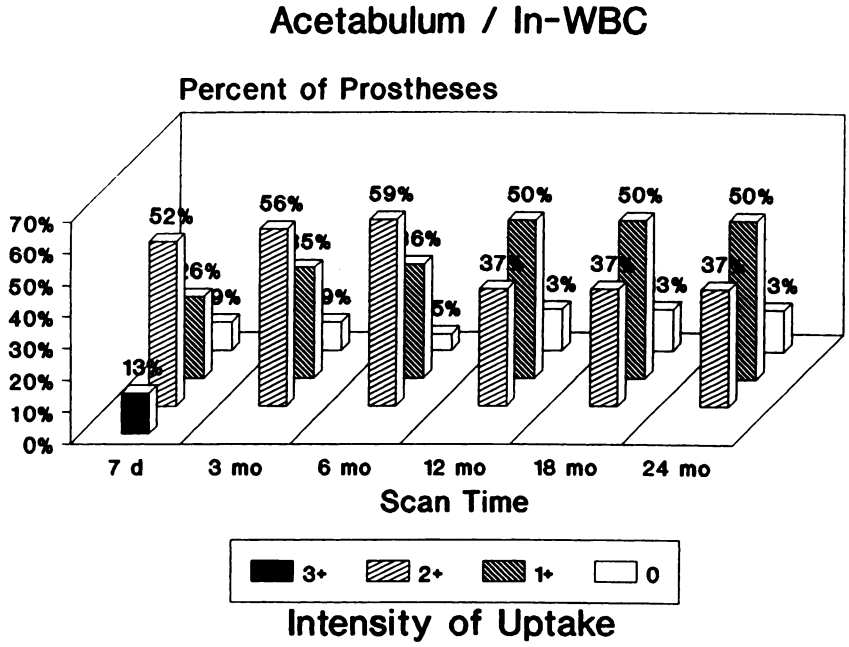

FIGURE 6
Considering the 25 prostheses as a group, the graph shows the percentage of prostheses demonstrating a given intensity of ^{111}In-WBC uptake at the acetabulum at the various scanning times.

vidual prosthesis demonstrated a clear trend toward stable or decreasing activity in the acetabulum (Fig. 4). This implies that an increase in intensity of uptake by one grade or more with serial scanning should raise the suspicion of a complication.

If the criteria of stable or decreasing activity is used as evidence against the existence of a complication, then comparison with a baseline study may be helpful. Consequently, we believe a baseline TPBS should be performed. Any time beyond the first few postoperative months would seem to be an appropriate time to obtain a baseline scan.

Several patterns of Tc-MDP uptake in the acetabulum were noted and are demonstrated in Figure 5. The most frequent configuration is increased activity in the superior aspect of the acetabulum. The recognition of the various patterns would not appear to be as important as the acknowledgment that activity almost always decreases or remains stable with time. Radiographic and scintigraphic evidence of heterotopic bone formation about the acetabulum were common and this should be considered in the interpretation of any increasing activity.

A number of papers have reported on the use of ^{111}In-WBC imaging in patients with painful or infected prostheses (*3,4,6,8–12*). We studied the prospective use of ^{111}In-WBC in the uncomplicated patient. Indium-111-WBC uptake was present at the acetabulum in 92% of prostheses at some time in our study and in 90% of scans. Therefore, the mere presence of ^{111}In-WBC uptake does not necessarily indicate infection. The intensity of ^{111}In-WBC uptake at the acetabulum was always less than or equal to the iliac crest with the exception of two patients exhibiting 3+ activity on the 7-day scan (Fig. 6). This implies that ^{111}In-WBC uptake greater than the iliac crest after the immediate postoperative period should be viewed with suspicion.

Analysis of intensity over time for each individual prosthesis invariably demonstrated stable or decreasing ^{111}In-WBC activity with serial scanning. When compared with the bone phase images, the intensity of ^{111}In-WBC uptake at the acetabulum was less than or equal to the intensity of Tc-MDP uptake in 98% of prostheses.

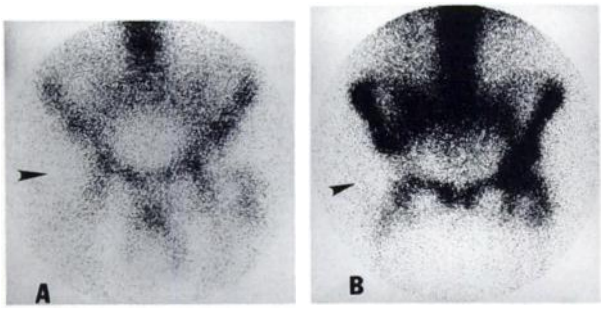

FIGURE 7
The patterns of ^{111}In-WBC uptake at the acetabulum are shown: (A) uniform uptake and (B) nonuniform uptake characterized by decreased activity centrally. Arrows indicate side evaluated.

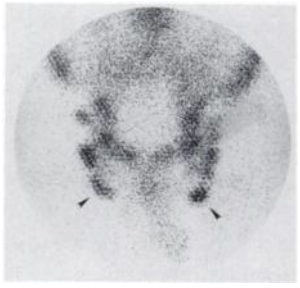

FIGURE 8
Example of focal areas of increased uptake (arrows), believed to represent ^{111}In-WBC uptake in lymph nodes, seen bilaterally in this patient with a right hip prosthesis.

Since the presence or absence of ^{111}In-WBC uptake at the acetabulum alone does not necessarily yield a diagnosis of infection and since consideration of changing activity with serial scanning may be helpful, a baseline scan becomes valuable. The baseline scan could be performed at any convenient time postoperatively.

Focal areas of ^{111}In-WBC uptake projecting over the inguinal regions were commonly seen and were believed to represent uptake in lymph nodes (*18*). This uptake, which was often multiple, was at times intermittent and could make its initial appearance as late as 12 mo postoperatively. Typically, this focal activity was small and of minimal intensity but occasionally could be larger and very intense. In this series, its intensity was always less than or equal to the iliac crest except for one patient who demonstrated uptake greater than iliac crest in two scans. Additionally, this uptake was not always restricted to the side of the arthroplasty. In evaluating the painful prosthesis with ^{111}In-WBC scintigraphy, one must guard against the overzealous interpretation of this focal activity as representing infection.

In summary, data for TPBS include:

1. No study showed increased blood flow.
2. Increased blood-pool activity was seen in 22% of the blood-pool images but was confined essentially to the 7-day and 3-mo scans.
3. Increased Tc-MDP uptake was universally seen at some time during the first 24 mo. However, intensity of Tc-MDP uptake was stable or decreasing during the 3- to 24-mo study interval (24 of 25 prostheses) with no prosthesis showing an increase in activity after 12 mo postoperatively.

For the ^{111}In-WBC studies:

1. Uptake was frequently present (92% of prostheses and 90% of scans) at some time during the first 24 mo.
2. The intensity of ^{111}In-WBC uptake was always less than or equal to the iliac crest from 3 to 24 mo.
3. The intensity of ^{111}In-WBC uptake was stable or decreasing in 100% of prostheses during the study.
4. The intensity of ^{111}In-WBC uptake was less than or equal to the intensity of Tc-MDP uptake in 98% of prostheses.

It is important to recognize that the recommendations cited below are unconfirmed and untested in a scientific prospective study. The fact that they did not observe a particular finding in our "normal" patient population does not imply that the presence of that finding should necessarily be considered abnormal. It is possible that due to the sample size and potential for sampling error we did not observe a particular finding when, in fact, that finding may also be frequently found in the uncomplicated patient.

RECOMMENDATIONS

Based on this two-year prospective study, we would make the following recommendations in interpreting Tc-MDP and ^{111}In-WBC scintigraphy as they pertain to the acetabulum of the porous-coated prosthesis:

TPBS:

1. Increased flow at any time or increased blood-pool activity after three months should strongly raise the suspicion of a complication.
2. The frequency of Tc-MDP uptake at 1 and 2 yr is greater than would be expected with a cemented prosthesis and its presence alone should not necessarily be interpreted as representing a complication.
3. One should consider the possibility of an existing complication when serial studies show increasing uptake from 3 to 24 mo.
4. A baseline TPBS is of value to evaluate changing intensity.
5. The type of prosthesis (porous-coated versus cemented) would appear to be important in study interpretation.

Indium-111-WBC:

1. The presence of ^{111}In-WBC uptake does not necessarily indicate the presence of infection.
2. Infection of the porous-coated prosthesis should remain in the differential diagnosis if there is: (a) ^{111}In-WBC uptake greater than the iliac crest, (b) any increasing ^{111}In-WBC uptake at any time on serial scanning, or (c) intensity of ^{111}In-WBC uptake greater than intensity of Tc-MDP uptake.
3. A baseline ^{111}In-WBC scan is of value to evaluate changing intensity.

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