The Value of Quantitative Uptake of $^{99m}$Tc-MDP and $^{99m}$Tc-HMPAO White Blood Cells in Detecting Osteomyelitis in Violated Peripheral Bones

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Our objective in this study was to evaluate whether measurement of quantitative uptake of $^{99m}$Tc-methylene diphosphate (MDP) and $^{99m}$Tc-hexamethylpropyleneamine oxime (HMPAO) white blood cells (WBCs) is useful in detecting osteomyelitis in peripheral bony lesions. Methods: Twenty-four patients (12 men and 12 women; age range, 25–72 y) were referred for imaging because of clinically suspected osteomyelitis. They had a traumatic fracture ($n = 10$), knee prosthesis ($n = 5$), hip prosthesis ($n = 2$), diabetic foot ($n = 4$), or chronic osteomyelitis ($n = 3$). Three-phase bone scanning and $^{99m}$Tc-HMPAO WBC studies were performed on all patients within the same week. Regions of interest were drawn over the abnormal bony sites and the contralateral normal sites, and the abnormal-to-normal uptake ratios (A/N ratios) were obtained for both studies. Results: All patients had abnormal findings on 3-phase bone scanning, whereas 17 (71%) had abnormal findings on $^{99m}$Tc-HMPAO WBC studies, of which 15 were confirmed to be true-positive. In those 15 patients, the mean A/N ratios for $^{99m}$Tc-MDP and $^{99m}$Tc-HMPAO WBC were $3.0 \pm 1.6$ (range, $1.3–6.2$) and $1.8 \pm 0.3$ (range, $1.4–2.2$), respectively. In the other 9 patients, whose scan results were clinically confirmed to be true-negative, the mean A/N ratios for $^{99m}$Tc-MDP and $^{99m}$Tc-HMPAO WBC were $2.1 \pm 1.2$ and $1.2 \pm 0.2$, respectively. In the group with a $^{99m}$Tc-MDP A/N ratio greater than 2 ($n = 15$), 87% (13/15) had a high $^{99m}$Tc-HMPAO WBC A/N ratio (>1.5), including 2 that were false-positive. In the remaining 2 patients, one with chronic osteomyelitis and the other with a recent hip prosthesis, $^{99m}$Tc-HMPAO WBC ratios were normal. In the group with a bone A/N ratio of less than 2 ($n = 9$), only 4 patients (44%) were true-positive for acute osteomyelitis. Conclusion: $^{99m}$Tc-MDP bone scanning alone, with an A/N ratio of more than 2, is useful in detecting osteomyelitis in violated bone except in the case of a recent hip prosthesis or chronic osteomyelitis.

Key Words: 3-phase bone scan; $^{99m}$Tc-HMPAO WBC; osteomyelitis; quantitative measurements

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Clinical and laboratory tests such as complete blood counting, C-reactive protein, and erythrocyte sedimentation rate are considered nonspecific for the diagnosis of osteomyelitis, whereas cultures of the blood or bone tissue are essential for a precise diagnosis (1). However, cultures are invasive, may spread infection from overlying soft tissue to underlying bone, and may induce pathologic fractures. Imaging is needed to confirm the diagnosis early, because a delay in treatment reduces the chance of cure. Prolonged treatment with intravenous antibiotics for 4–6 wk cannot be given without an accurate diagnosis (2,3). The bone scan has an established role in detecting bone infection. Normal results on a bone scan rule out osteomyelitis (4). The classic findings of hyperemia, increased blood-pool activity, and increased focal bony uptake on delayed images on 3-phase bone imaging are sensitive and specific for the diagnosis of osteomyelitis in nonviolated bone (5,6). Violated bone hampers the detection of infection on the basis of these classic findings because increased bone turnover and, perhaps, hyperemia are already present. Therefore, despite high bone scan sensitivity, pathologic orthopedic (violated bone) cases have a lowered specificity for the detection of osteomyelitis (7). The sensitivity of 3-phase bone imaging has been reported to be between 70% and 100%, with an average of 92%, whereas the average specificity might be as low as 32% (8). Because labeled leukocytes do not accumulate at the site of increased bone turnover, the addition of $^{99m}$Tc-hexamethylpropyleneamine oxime (HMPAO) white blood cell (WBC) imaging has been helpful in diagnosing bone infection in violated bones, such as after trauma, after surgery, and from diabetic foot infection (9–11). The
overall \textsuperscript{99m}Tc-HMPAO WBC sensitivity and specificity are 88% and 91%, respectively, in osteomyelitis of previously violated bones (9,12–14). However, \textsuperscript{99m}Tc-HMPAO WBC imaging is performed only after a positive finding on 3-phase bone imaging, because the latter is highly sensitive but significantly less expensive, making it more appropriate as a first-line screening procedure (3).

Previous attempts have been made to improve the specificity of 3-phase bone imaging. The use of 4 phases has been reported to improve accuracy in differentiating osteomyelitis from cellulitis by showing an increase in the ratio between the lesion and normal bone due to longer uptake of \textsuperscript{99m}Tc-methylene diphosphonate (MDP) by infected than by healthy bone and to the reduction of background activity (15,16). Seldin et al. attempted to improve the sensitivity of 3-phase bone imaging in diabetic patients by classifying increased activity on the flow phase of the study (hyperemia) according to the time of its appearance relative to the surrounding soft tissues (17).

In addition to qualitatively assessing the \textsuperscript{99m}Tc-MDP and \textsuperscript{99m}Tc-HMPAO WBC studies, we have attempted to evaluate the clinical usefulness of measuring quantitative uptake in \textsuperscript{99m}Tc-MDP and \textsuperscript{99m}Tc-HMPAO WBC scanning in detecting osteomyelitis in peripheral bony lesions. In this study, our attempt was to investigate the usefulness of quantifying the degree of \textsuperscript{99m}Tc-MDP uptake on bone scanning and to compare it with the degree of \textsuperscript{99m}Tc-HMPAO uptake on WBC scanning, in patients with suspected osteomyelitis.

MATERIALS AND METHODS

This study was conducted between 2000 and 2003 at the Kuwait Center for Specialised Surgery. Twenty-four patients with violated bone (12 men and 12 women; age range, 25–72 y) were referred to the nuclear medicine department with a clinical suspicion of osteomyelitis. The patients underwent 3-phase \textsuperscript{99m}Tc-MDP bone scanning first, followed by \textsuperscript{99m}Tc-HMPAO WBC scanning. The studies were separated by at least 2 d but no more than 7 d. The underlying bone pathology included traumatic fracture (n = 10), knee prosthesis (n = 5), hip prosthesis (n = 2), diabetic foot (n = 4), and chronic osteomyelitis (n = 3). In both studies, the amount of intravenously injected \textsuperscript{99m}Tc was about 740 MBq (~20 mCi), and images were acquired by a \gamma-camera with a high-resolution parallel-hole collimator using a matrix of 256 × 256 (pixel size, ~2 mm) on a 20% window at a 140-keV peak. Anterior images were obtained 3 h after \textsuperscript{99m}Tc-MDP injection and 4 h after \textsuperscript{99m}Tc-HMPAO leukocyte injection.

Three nuclear medicine consultants qualitatively evaluated the scintigraphic findings of both studies. The \textsuperscript{99m}Tc-HMPAO–labeled WBC and \textsuperscript{99m}Tc-MDP scans were considered to be consistent with osteomyelitis when the labeled WBC scan uptake was concordant in all instances with \textsuperscript{99m}Tc-MDP bone uptake. \textsuperscript{99m}Tc-HMPAO WBC uptake without concordant bone \textsuperscript{99m}Tc-MDP activity was considered to indicate a soft-tissue infection. The results of the \textsuperscript{99m}Tc-HMPAO WBC and \textsuperscript{99m}Tc-MDP scans were compared with the following diagnostic criteria: A good response to antibiotic therapy and resolving radiologic findings were considered diagnostic of osteomyelitis; absence of bone infection was also confirmed by uneventful clinical and radiologic follow-up. The nuclear medicine physician asked for a bone marrow scan whenever altered bone marrow distribution was suspected—for example, in a diabetic foot.

Both the \textsuperscript{99m}Tc-MDP bone scans and the \textsuperscript{99m}Tc-HMPAO WBC scans were further analyzed by drawing equal rectangular regions of interest over the suspected abnormal and contralateral normal bone sites (mirrored regions of interest). The entire lesion was included in the rectangular region of interest. Mean counts per pixel in each region of interest were estimated. The mean uptake count ratio between abnormal and normal sites (A/N) in \textsuperscript{99m}Tc-MDP bone and \textsuperscript{99m}Tc-HMPAO WBC scans were obtained. A/N ratios were assessed by an unpaired 2-way Student t test applied to the \textsuperscript{99m}Tc-MDP bone and \textsuperscript{99m}Tc-HMPAO WBC scans using version 12.0 SPSS software (SPSS Inc.) for Windows (Microsoft).

RESULTS

Figure 1 shows 2 different patients. Although both had positive findings on \textsuperscript{99m}Tc-MDP scanning, the first patient had negative findings on \textsuperscript{99m}Tc-HMPAO scanning whereas the second had positive findings. All patients had abnormal 3-phase bone findings, whereas 17 (71%) had concordant

![FIGURE 1. Anterior-view \textsuperscript{99m}Tc-HMPAO WBC scans (left) and \textsuperscript{99m}Tc-MDP bone scans (right). (A) Images of patient with negative \textsuperscript{99m}Tc-HMPAO findings but positive \textsuperscript{99m}Tc-MDP findings, showing regions of interest drawn on suspected site of abnormality and on contralateral normal site. (B) Patient with positive findings on both types of scans.](image-url)
abnormal findings on 99mTc-HMPAO WBC scanning and therefore were considered to have osteomyelitis, which was confirmed on follow-up in 15 of 17 (Table 1). In the 15 true-positive osteomyelitis patients, the mean A/N ratios on 99mTc-MDP and 99mTc-HMPAO WBC scans were 3.0 ± 1.6 (range, 1.3–6.2) and 1.8 ± 0.3 (range, 1.4–2.2), respectively. In the remaining 9 patients, clinically confirmed negative, the mean A/N ratios for 99mTc-MDP and 99mTc-HMPAO WBC were 2.1 ± 1.2 and 1.2 ± 0.2, respectively (Table 2). The derived 99mTc-HMPAO WBC mean A/N ratios were significantly different between patients who were positive and patients who were negative for osteomyelitis (Table 2).

We considered a mean A/N ratio of 2, or twice the normal uptake, to be significantly abnormal on 99mTc-MDP bone scanning and further analyzed our data accordingly (Table 3). Of the 15 patients with an A/N ratio of more than 2 (mean, 3.4 ± 1.3) on 99mTc-MDP bone scanning, 13 (87%) had a mean A/N ratio of more than 1.5 (mean, 1.8 ± 0.3) on 99mTc-HMPAO WBC scanning, of whom 2 were false-positive for osteomyelitis. The remaining 2 had 99mTc-HMPAO WBC A/N ratios of 1.2 (hip prosthesis) and 1.1 (chronic osteomyelitis) and were true-negative for acute osteomyelitis. Of the 9 patients with 99mTc-MDP A/N ratios of less than 2 (mean, 1.4 ± 0.1), 4 (44%) were confirmed to have osteomyelitis, of whom 2 had an 99mTc-HMPAO WBC A/N ratio equal to or above 1.5 and the other 2 had a 99mTc-HMPAO WBC A/N ratio of 1.4 (Table 3).

We evaluated 10 patients with complicated fractures for acute osteomyelitis. Five were confirmed to have osteomyelitis, all having a 99mTc-HMPAO WBC A/N ratio of more than 1.5 and a 99mTc-MDP A/N ratio of more than 2. One patient with 99mTc-MDP bone A/N ratios of less than 2 (mean, 1.4 ± 0.1), 4 (44%) were confirmed to have osteomyelitis, of whom 2 had an 99mTc-HMPAO WBC A/N ratio equal to or above 1.5 and the other 2 had a 99mTc-HMPAO WBC A/N ratio of 1.4 (Table 3).

**Table 1**

Quantitative 99mTc-MDP and 99mTc-HMPAO WBC Scan Results in Violated Peripheral Bone with Their Definitive Diagnosis

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Underlying pathology</th>
<th>99mTc-MDP A/N</th>
<th>99mTc-HMPAO A/N</th>
<th>Scan report</th>
<th>Diagnostic criteria</th>
<th>Antibiotic therapy</th>
<th>Definitive diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fracture</td>
<td>1.3</td>
<td>1.1</td>
<td>Negative</td>
<td>Clinical</td>
<td>No</td>
<td>TN</td>
</tr>
<tr>
<td>2</td>
<td>Fracture</td>
<td>2.6</td>
<td>2.2</td>
<td>Positive</td>
<td>Bone biopsy</td>
<td>Yes</td>
<td>TP</td>
</tr>
<tr>
<td>3</td>
<td>Fracture</td>
<td>1.4</td>
<td>1.2</td>
<td>Negative</td>
<td>Clinical</td>
<td>No</td>
<td>TN</td>
</tr>
<tr>
<td>4</td>
<td>Fracture</td>
<td>2.7</td>
<td>1.6</td>
<td>Positive</td>
<td>Bone biopsy</td>
<td>No</td>
<td>FP</td>
</tr>
<tr>
<td>5</td>
<td>Fracture</td>
<td>4.1</td>
<td>1.9</td>
<td>Positive</td>
<td>Bone biopsy</td>
<td>Yes</td>
<td>TP</td>
</tr>
<tr>
<td>6</td>
<td>Fracture</td>
<td>2.4</td>
<td>1.5</td>
<td>Positive</td>
<td>Bone biopsy</td>
<td>Yes</td>
<td>TP</td>
</tr>
<tr>
<td>7</td>
<td>Fracture</td>
<td>1.3</td>
<td>1.2</td>
<td>Negative</td>
<td>Clinical</td>
<td>No</td>
<td>TN</td>
</tr>
<tr>
<td>8</td>
<td>Fracture</td>
<td>2.2</td>
<td>1.5</td>
<td>Positive</td>
<td>Clinical</td>
<td>Yes</td>
<td>TP</td>
</tr>
<tr>
<td>9</td>
<td>Fracture</td>
<td>2.9</td>
<td>1.8</td>
<td>Positive</td>
<td>Bone biopsy</td>
<td>Yes</td>
<td>TP</td>
</tr>
<tr>
<td>10</td>
<td>Fracture</td>
<td>1.3</td>
<td>1.4</td>
<td>Positive</td>
<td>Clinical</td>
<td>Yes</td>
<td>TP</td>
</tr>
<tr>
<td>11</td>
<td>Prosthesis</td>
<td>2.1</td>
<td>1.5</td>
<td>Positive</td>
<td>Bone biopsy</td>
<td>Yes</td>
<td>TP</td>
</tr>
<tr>
<td>12</td>
<td>Prosthesis</td>
<td>1.4</td>
<td>1.5</td>
<td>Positive</td>
<td>Bone biopsy</td>
<td>Yes</td>
<td>TP</td>
</tr>
<tr>
<td>13</td>
<td>Prosthesis</td>
<td>2.1</td>
<td>1.7</td>
<td>Positive</td>
<td>Clinical</td>
<td>No</td>
<td>FP</td>
</tr>
<tr>
<td>14</td>
<td>Prosthesis</td>
<td>1.3</td>
<td>1.4</td>
<td>Positive</td>
<td>Bone biopsy</td>
<td>Yes</td>
<td>TP</td>
</tr>
<tr>
<td>15</td>
<td>Prosthesis</td>
<td>1.6</td>
<td>2.1</td>
<td>Positive</td>
<td>Bone biopsy</td>
<td>Yes</td>
<td>TP</td>
</tr>
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<td>16</td>
<td>Prosthesis</td>
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<td>2.1</td>
<td>Positive</td>
<td>Bone biopsy</td>
<td>Yes</td>
<td>TP</td>
</tr>
<tr>
<td>17</td>
<td>Prosthesis</td>
<td>4.8</td>
<td>1.2</td>
<td>Negative</td>
<td>Clinical</td>
<td>No</td>
<td>TN</td>
</tr>
<tr>
<td>18</td>
<td>Diabetic foot ulcers</td>
<td>6.2</td>
<td>2.1</td>
<td>Positive</td>
<td>Bone biopsy</td>
<td>Yes</td>
<td>TP</td>
</tr>
<tr>
<td>19</td>
<td>Diabetic foot ulcers</td>
<td>5.0</td>
<td>2.0</td>
<td>Positive</td>
<td>Bone biopsy</td>
<td>Yes</td>
<td>TP</td>
</tr>
<tr>
<td>20</td>
<td>Diabetic foot ulcers</td>
<td>4.4</td>
<td>2.1</td>
<td>Positive</td>
<td>Bone biopsy</td>
<td>Yes</td>
<td>TP</td>
</tr>
<tr>
<td>21</td>
<td>Diabetic foot ulcers</td>
<td>4.8</td>
<td>2.0</td>
<td>Positive</td>
<td>Bone biopsy</td>
<td>Yes</td>
<td>TP</td>
</tr>
<tr>
<td>22</td>
<td>Chronic osteomyelitis</td>
<td>2.9</td>
<td>1.1</td>
<td>Negative</td>
<td>Clinical</td>
<td>No</td>
<td>TN</td>
</tr>
<tr>
<td>23</td>
<td>Chronic osteomyelitis</td>
<td>1.3</td>
<td>1.0</td>
<td>Negative</td>
<td>Clinical</td>
<td>No</td>
<td>TN</td>
</tr>
<tr>
<td>24</td>
<td>Chronic osteomyelitis</td>
<td>1.3</td>
<td>1.1</td>
<td>Negative</td>
<td>Clinical</td>
<td>No</td>
<td>TN</td>
</tr>
</tbody>
</table>

**Table 2**

Quantitative Results for Both Studies in 24 Patients with Violated Peripheral Bones

<table>
<thead>
<tr>
<th>Definitive diagnosis</th>
<th>99mTc-MDP A/N (mean ± SD)</th>
<th>P value</th>
<th>99mTc-HMPAO A/N (mean ± SD)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>3.0 ± 1.6</td>
<td>&lt;0.001</td>
<td>1.8 ± 0.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Negative</td>
<td>2.1 ± 1.2</td>
<td>&gt;0.05</td>
<td>1.2 ± 0.2</td>
<td>&gt;0.05</td>
</tr>
</tbody>
</table>

P value was derived using 2-way unpaired Student t test.

Negative = 99mTc-MDP and 99mTc-HMPAO WBC scans reported negative for osteomyelitis; positive = 99mTc-MDP and 99mTc-HMPAO WBC scans reported positive for osteomyelitis; clinical = clinical follow-up shows good response to antibiotic therapy and resolving radiologic and clinical findings; absence of bone infection was also confirmed by uneventful clinical and radiologic follow up without antibiotic therapy.

Definitive diagnostic criterion was bone biopsy with culture and sensitivity. For bone scanning, sensitivity = 100% and specificity = 30%. For HMPAO WBC scanning, sensitivity = 100% and specificity = 78%.
quantitative results for both studies in 15 and 9 patients with a mean 99mTc-MDP A/N ratio of more than 2.0 and less than 2.0, respectively.

<table>
<thead>
<tr>
<th>MDP A/N ratio</th>
<th>HMPAO A/N ratio n (24)</th>
<th>≥1.5 (1.2 ± 0.1)</th>
<th>≥1.5 (1.8 ± 0.3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥2.0 (3.4 ± 1.3)</td>
<td>15</td>
<td>2/15 (13%)</td>
<td>13/15 (87%)</td>
</tr>
<tr>
<td>&lt;2.0 (1.4 ± 0.1)</td>
<td>9</td>
<td>7/9 (78%)*</td>
<td>2/9 (22%)</td>
</tr>
</tbody>
</table>

*Two of 9 patients were true-positive for osteomyelitis.

Quantitative Results for Both Studies in 15 and 9 Patients

We evaluated 7 patients 6 mo to 3 y after prosthetic implantation. Five of the 7 were confirmed to have acute osteomyelitis, of whom 4 had a 99mTc-HMPAO WBC A/N ratio of at least 1.5 and a 99mTc-MDP A/N ratio of more than 2. A high bone uptake is expected in these patients because of underlying neuropathic bone changes. Previous studies with combined 99mTc-HMPAO/MDP imaging in diabetic foot ulcers prove to be useful in diagnosing osteomyelitis (18,22). Poirier et al. reported a sensitivity of 92.6% and a specificity of 97.6% for 99mTc-HMPAO/MDP scanning for the diagnosis of osteomyelitis in diabetic foot ulcers and concluded that neuroarthropathy did not affect the performance of this scan (23).

We evaluated 7 patients 6 mo to 3 y after prosthetic implantation. Five of the 7 were confirmed to have acute osteomyelitis, of whom 4 had a 99mTc-HMPAO A/N ratio of more than 1.5. These patients have shown variable bone uptake. Four had a 99mTc-MDP A/N ratio of more than 2, of whom one was reported falsely positive for osteomyelitis whereas the other, with a recent hip prosthesis, was correctly diagnosed on 99mTc-HMPAO WBC scanning to have no acute osteomyelitis although he had an 99mTc-MDP A/N ratio of 4.8. These results are consistent with the well-known fact that periprosthetic uptake patterns are variable during the first 12 mo after joint replacement, and accordingly, it appears that bone scanning is most useful in excluding infections when the findings are clearly negative (24,25). Therefore, the addition of 99mTc-HMPAO WBC scanning proved useful in detecting osteomyelitis (4/5 patients; A/N ratio, >1.5). Copping et al. found 99mTc-HMPAO WBC scanning to be useful for the evaluation of orthopedic implant infection after positive findings on 3-phase bone scanning (3). De Lima Ramos et al. reported a sensitivity, specificity, and accuracy of 72.7%, 78.2%, and 76.4%, respectively, for 99mTc-HMPAO WBC scanning for the localization of bone and joint infections (26). False-positive

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Quantitative Results for Both Studies in 15 and 9 Patients

We evaluated 7 patients 6 mo to 3 y after prosthetic implantation. Five of the 7 were confirmed to have acute osteomyelitis, of whom 4 had a 99mTc-HMPAO WBC A/N ratio of at least 1.5 and a 99mTc-MDP A/N ratio of more than 2. A high bone uptake is expected in these patients because of underlying neuropathic bone changes. Previous studies with combined 99mTc-HMPAO/MDP imaging in diabetic foot ulcers prove to be useful in diagnosing osteomyelitis (18,22). Poirier et al. reported a sensitivity of 92.6% and a specificity of 97.6% for 99mTc-HMPAO/MDP scanning for the diagnosis of osteomyelitis in diabetic foot ulcers and concluded that neuroarthropathy did not affect the performance of this scan (23).

We evaluated 7 patients 6 mo to 3 y after prosthetic implantation. Five of the 7 were confirmed to have acute osteomyelitis, of whom 4 had a 99mTc-HMPAO A/N ratio of more than 1.5. These patients have shown variable bone uptake. Four had a 99mTc-MDP A/N ratio of more than 2, of whom one was reported falsely positive for osteomyelitis whereas the other, with a recent hip prosthesis, was correctly diagnosed on 99mTc-HMPAO WBC scanning to have no acute osteomyelitis although he had an 99mTc-MDP A/N ratio of 4.8. These results are consistent with the well-known fact that periprosthetic uptake patterns are variable during the first 12 mo after joint replacement, and accordingly, it appears that bone scanning is most useful in excluding infections when the findings are clearly negative (24,25). Therefore, the addition of 99mTc-HMPAO WBC scanning proved useful in detecting osteomyelitis (4/5 patients; A/N ratio, >1.5). Copping et al. found 99mTc-HMPAO WBC scanning to be useful for the evaluation of orthopedic implant infection after positive findings on 3-phase bone scanning (3). De Lima Ramos et al. reported a sensitivity, specificity, and accuracy of 72.7%, 78.2%, and 76.4%, respectively, for 99mTc-HMPAO WBC scanning for the localization of bone and joint infections (26). False-positive
99mTc-HMPAO WBC scans are possible in conditions such as periprosthetic granuloma, ossifying periarthritis, non-specific bone inflammation negative for bacterial growth, and physiologic uptake by cellular bone marrow. Munoz et al. stated that the addition of bone marrow scintigraphy with 99mTc-stannous colloid to the 99mTc-HMPAO WBC/MDP scan protocol improved the accuracy of the diagnosis of bone prosthesis infection and should be included in the diagnostic protocol for this disease (27). In our study, a quantitative 99mTc-HMPAO WBC A/N ratio of more than 1.5 correctly identified the presence of osteomyelitis in 4 of 5 patients. Therefore, our findings suggest that adding quantitation to the 99mTc-HMPAO WBC scan could be significantly valuable in detecting osteomyelitis in patients with prosthesis transplants.

Of 10 patients with complicated fractures, 5 were correctly identified as having osteomyelitis on 99mTc-MDP bone scanning (A/N ratio, >2), and all 5 had a 99mTc-HMPAO WBC A/N ratio of more than 1.5. One patient was falsely reported to have osteomyelitis on the combined 99mTc-MDP/HMPAO WBC study. This patient had no abnormal uptake at the fracture site on the 99mTc-HMPAO WBC scan but had an actual increase in tracer localization at a bony site distal to the fracture on both 99mTc-MDP and 99mTc-HMPAO WBC scans. The patient had an uneventful course with no antibiotic treatment. Three patients with chronic osteomyelitis were correctly diagnosed to have no acute osteomyelitis on 99mTc-HMPAO WBC scanning (A/N ratio, 1.1). Only one patient had 99mTc-MDP uptake of more than 2. Although the number of patients in this study was small, similar results have been reported by Krznaric et al., who found that 99mTc-HMPAO WBC scanning had an overall sensitivity, specificity, and accuracy of 94%, 91%, and 92%, respectively, for the diagnosis of chronic osteomyelitis (28).

**CONCLUSION**

This study found a high correlation between qualitative and quantitative diagnosis in suspected cases of violated bone infection using combined 99mTc-MDP/HMPAO WBC scanning. Uptake measurements were easy to perform. 99mTc-MDP bone scanning alone, with an A/N ratio of more than 2, was useful in detecting osteomyelitis in violated bone, if one kept in mind the possibility of variable bone uptake in certain settings such as prosthetic implants and chronic osteomyelitis. These preliminary findings suggest that an uptake of more than 1.5 on 99mTc-HMPAO WBC scanning can be of value in detecting osteomyelitis.

**REFERENCES**

The Value of Quantitative Uptake of $^{99m}$Tc-MDP and $^{99m}$Tc-HMPAO White Blood Cells in Detecting Osteomyelitis in Violated Peripheral Bones

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