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Evaluation of Infections of the Locomotor System with Indium-111-Labeled Human IgG Scintigraphy

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Indium-111-labeled human nonspecific immunoglobulin G (\(^{111}\)In-IgG) is one of the newer agents suggested for scintigraphic evaluation of infection and inflammation. In this study, the utility of this agent was studied in routine clinical practice. **Methods:** A dose of 75 MBq \(^{111}\)In labeled to 2 mg IgG (MacroScint®) was administered intravenously in 226 patients with 232 possible foci of infection or inflammation. Imaging was performed 4, 24 and 48 hr postinjection. The results were verified by culture, obtained either surgically (42%) or via puncture (19%) and long-term clinical and roentgenological follow-up (39%). Follow-up data were used in patients of whom the vast majority had a negative work-up, including negative \(^{111}\)In-IgG scintigraphy. **Results:** All infected total hip (THA) and total knee arthroplasties, focal osteomyelitis, diabetic foot infections, septic arthritis and soft-tissue infections were detected (61 foci). Only one patient with early, low-grade spondylodiscitis was false negative with \(^{111}\)In-IgG. Since \(^{111}\)In-IgG scintigraphy does not discriminate between infectious and sterile inflammation, careful interpretation is necessary in cementless THA up to 1 yr after insertion, uptake only around the neck of the femoral component of a THA, recent fractures and pseudarthrosis, in which uptake may be caused by sterile inflammation and not by infection (specificity for inflammation 100%, specificity for infection 77%). **Conclusion:** Indium-111-IgG scintigraphy is a very sensitive tool for detection of infectious bone and joint disease. Moreover, when uptake patterns of \(^{111}\)In-IgG, which are characteristic for sterile inflammation, are excluded, infection can be ruled out with a high degree of certainty. **Key Words:** indium-111; spondylodiscitis; arthroplasty; diabetic foot; osteomyelitis

**MATERIALS AND METHODS**

**Patients**

The studies of 243 patients, obtained over a period of 4 yr, were reviewed. Of these 243 patients, 226 (108 male and 118 female; mean age 54.3 yr, with a range of 5-90 yr), suspected of 232 possible foci of infection, were evaluable. Previously published patient data, which were obtained before patients were recruited for this study, were not included (9,10). The patients were categorized on the basis of the suspected focus: total hip arthroplasty (n = 87; 38%), total knee arthroplasty (n = 17; 7%), chronic osteomyelitis (n = 43; 18%), diabetic foot osteomyelitis (n = 22; 9%), pseudarthrosis (n = 11; 5%), septic arthritis (n = 16; 7%), noninfectious arthritis (n = 13; 6%), soft-tissue infection (n = 7; 3%) or spondylodiscitis/vertebral osteomyelitis (n = 16; 7%). Acute osteomyelitis was defined as evidence of infection for one or several days, chronic osteomyelitis as evidence of infection for weeks, months or even years (9).

**Radiopharmaceuticals**

DTPA-conjugated human nonspecific polyclonal IgG was obtained as a lyophilized kit containing 2 mg IgG per vial (MacroScint, RW Johnson Pharmaceutical Research Institute, Spring House, PA). The kit was radiolabeled with \(^{111}\)In (Indium-111 chloride, Mallinkrodt Medical, Petten, The Netherlands) in a 15-min, one-step procedure according to the manufacturer’s instructions. The radiochemical purity as determined by instant thin layer chromatography was always higher than 95%. A dose of approximately 2 mg IgG, labeled with 75 MBq \(^{111}\)In was injected intravenously. Within 1 mo of the \(^{111}\)In-IgG scintigraphy, two- or three-phase skeletal scintigraphy was performed in 135 patients after intravenous injection of methylene diphosphonate labeled with 600 MBq of \(^{99m}\)Tc. The maximum time interval was only considered in chronic cases and only when no invasive diagnostic or therapeutic
interventions were performed. In acute cases, the studies were all performed within a few days.

**Imaging Procedure and Image Interpretation**

Scintigraphic imaging was performed as reported earlier (8). In brief, digital images were obtained with a Siemens Orbiter gamma camera connected to a Scintiview image processor (Siemens Inc., Hoffman Estates, IL). Indium-111-IgG images were acquired at 4, 18–24 and 42–48 hr postinjection.

All images were interpreted by three observers. The observers were not blinded for pretest clinical information. A definite judgment of the scintigraphic images was reached before any of the verification procedures was performed. The $^{111}$In-IgG images were interpreted with the corresponding bone scintigraphy, when available. A $^{111}$In-IgG scan was interpreted as positive; if focal, continuously increasing accumulation could be noted over time. Nonvisualization of the lesion detected by bone scan and/or plain radiographs, or failure to show increasing accumulation, was considered to be a negative $^{111}$In-IgG scintigraphy. A bone scan was considered positive when there was increased activity in at least two phases (blood pool and late phase) in the area of interest.

**Verification**

The scintigraphic results were verified by culture, obtained surgically (n = 98, 42%) or by puncture (n = 43, 19%) or long-term clinical and roentgenological follow-up of at least 1 yr (n = 91, 39%). The latter was mainly used in patients with negative diagnostic work-up, including negative scintigraphic imaging.

**RESULTS**

The overall infection prevalence was 27% (62 foci). *Staphylococcus* species were cultured from 17 foci (38%), *Streptococcus* species from 13 foci (29%), *Pseudomonas aeruginosa* from 3 foci (7%) and a variety of other microorganisms or mixed flora from 12 foci (27%).

Nineteen patients received antibiotics before $^{111}$In-IgG scintigraphy, including ß-lactam antibiotics, (n = 17), tetracycline (n = 1) and fluorochinon (n = 1). Twelve scintigrams of these patients were scored true-positive, 5 true negative, 1 false-positive and 1 false-negative.

Table 1 summarizes the results of $^{111}$In-IgG scintigraphy in various patient categories.

<table>
<thead>
<tr>
<th>Diagnostic Procedure</th>
<th>True-positive (TP)</th>
<th>False-positive (FP)</th>
<th>True-negative (TN)</th>
<th>False-negative (FN)</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Hip Arthroplasty (n = 87)</strong></td>
<td>21</td>
<td>12</td>
<td>54</td>
<td>0</td>
<td>100</td>
<td>82</td>
<td>64</td>
<td>100</td>
</tr>
<tr>
<td><strong>Total knee Arthroplasty</strong></td>
<td>17</td>
<td>3</td>
<td>7</td>
<td>0</td>
<td>100</td>
<td>50</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td><strong>Chronic osteomyelitis</strong></td>
<td>43</td>
<td>15</td>
<td>2</td>
<td>26</td>
<td>0</td>
<td>100</td>
<td>93</td>
<td>83</td>
</tr>
<tr>
<td><strong>Diabetic foot osteomyelitis</strong></td>
<td>22</td>
<td>7</td>
<td>5</td>
<td>10</td>
<td>0</td>
<td>100</td>
<td>67</td>
<td>58</td>
</tr>
<tr>
<td><strong>Pseudarthrosis</strong></td>
<td>11</td>
<td>2</td>
<td>8</td>
<td>1</td>
<td>100</td>
<td>11</td>
<td>20</td>
<td>100</td>
</tr>
<tr>
<td><strong>Septic arthritis</strong></td>
<td>16</td>
<td>5</td>
<td>2</td>
<td>9</td>
<td>0</td>
<td>100</td>
<td>82</td>
<td>71</td>
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<tr>
<td><strong>Noninfectious arthritis</strong></td>
<td>13</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>—</td>
<td>100</td>
<td>—</td>
</tr>
<tr>
<td><strong>Soft-tissue infection</strong></td>
<td>7</td>
<td>6</td>
<td>0</td>
<td>1</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td><strong>Spondylodisciitis/vertebral osteomyelitis</strong></td>
<td>16</td>
<td>2</td>
<td>0</td>
<td>13</td>
<td>1</td>
<td>67</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>99</td>
<td>77</td>
<td>67</td>
<td>99</td>
</tr>
</tbody>
</table>

TP = true-positive; FP = false-positive; TN = true-negative; FN = false-negative; PPV = positive predictive value; NPV = negative predictive value.

**TABLE 1**

Results of Indium-111-IgG Scintigraphy for Detection of Infection in Various Patients

implanted 16 mo or longer before scintigraphy, while cemented hip arthroplasties were recorded as true-negative as early as 6 wk after implantation.

Twelve hip arthroplasties were recorded as false-positive, including nine cementless implants. Six of the latter had been implanted within a 14-mo period before $^{111}$In-IgG scintigraphy. Other causes of false-positive results included foreign body response after wear of the polyethylene socket (n = 1) and periarticular ossification (n = 1). One patient with increased $^{111}$In-IgG uptake on scintigraphy 6 mo after hip arthroplasty still had a wound with signs of inflammation (redness, induration) at time of imaging. One month later, however, this patient was free of complaints. In four of seven hip arthroplasties with increased $^{111}$In-IgG uptake located around the neck of the femoral component, no infection was found.

Histologic specimens were available from six false-positive hip implants. All showed signs of sterile chronic inflammation.

**Total Knee Arthroplasties (n = 17)**

All three infected knee arthroplasties showed increased $^{111}$In-IgG uptake on scintigraphy. Seven of 14 noninfected knee arthroplasties were scored false-positive. In one patient, infection was less likely since 1 mo after scintigraphy knee pain decreased, and the sedimentation rate of erythrocytes dropped without specific treatment. The positive $^{111}$In-IgG scintigraphy in this patient, performed 7 wk after arthroplasty, remained unexplained, other than being caused by the surgical procedure itself. One false-positive scan consisted of increased $^{111}$In-IgG uptake on scintigraphy 11 mo after total knee arthroplasty, which was caused by calcifications in the knee capsule seen on radiography. Three false-positive results consisted of scintigrams with clear focal $^{111}$In-IgG accumulation, but the location of this uptake was noted to be probably caused by noninfectious inflammation of soft tissues rather than infection located in bone around the arthroplasty itself.

Five false-positive results were scored based on negative cultures from needle aspirations (n = 4) and arthroscopy (n = 1). However, in all four available histologic specimens, signs of inflammation were seen.

**Chronic Osteomyelitis (n = 43)**

All 15 patients with proven chronic osteomyelitis showed increased $^{111}$In-IgG uptake on scintigraphy. Two of the 28 foci that were proven to be noninfected were scored as false-positives. The first patient suffered from severe decubitus on the lateral side of her right hip. Soft-tissue cultures grew *Escherichia coli* and *Enterococcus faecalis*. Within 1 mo, the wound healed and resection of the head of the hip was not
performed. In this patient, it was not possible to differentiate between increased $^{111}\text{In}$-IgG uptake in soft tissue or bone. In the second patient an above-knee amputation was performed 10 mo before scintigraphy due to a late complication of diabetes mellitus. A fistula at the amputation side existed for several months. Culture of the pus revealed \textit{S. aureus} in low counts. No evident signs of osteomyelitis were seen on plain radiography. Indium-$^{111}\text{In}$-IgG scintigraphy was scored as false-positive because the wound healed within 4 wk after scintigraphy, 3 wk after oral antibiotics only (amoxicillin–clavulanic acid).

Diabetic Foot Osteomyelitis (n = 22)

Seventeen foci in patients with a diabetic foot were adequately evaluated with $^{111}\text{In}$-IgG scintigraphy: 7 osteomyelitis, 10 no osteomyelitis (normal scan or soft-tissue inflammation only). Five foci in patients with a diabetic foot were recorded false-positive. Two of these patients had deep ulcers on the heel, culture revealed \textit{S. aureus} species and \textit{Proteus vulgaris}. In the first patient, histologic specimens from the ulcer showed no signs of osteomyelitis, whereas in the other patient the ulcer was healing rapidly 2 wk after scintigraphy with oral flucloxacillin (4 g/day). Three false-positive results were from patients with Charcot joints with recent fractures, who responded well to conservative treatment.

Pseudarthrosis (n = 11)

In only two patients, a positive $^{111}\text{In}$-IgG scintigram could be confirmed as positive for infection. Surgically obtained cultures proved infection in one patient with positive $^{111}\text{In}$-IgG scintigraphy 3 mo after removal of osteosynthesis material from his tibia. In the other patient, infection was evident based on a continuing producing fistula for several months from an internal fixator of the femur, being 1 yr in situ at the time of imaging.

One pseudarthrosis in a tibia with an external fixator placed 16 mo before imaging was true-negative, and subsequently proven by a negative culture.

Eight patients with pseudarthrosis showed false-positive focal accumulation of $^{111}\text{In}$-IgG on scintigraphy. Surgically obtained cultures were negative and no histologic evidence for infection was found in these patients. Five of eight patients had undergone removal of internal (n = 4) or external (n = 1) fixators from femur (n = 3) or tibia (n = 2) at least 3 mo before scintigraphy. In the remaining three patients the following surgical procedures had been performed: implantation of a dynamic hipscrew 1 yr before imaging, osteotomy of a tibia 5 mo and arthrodesis of an ankle 14 mo before scintigraphy, respectively.

Arthritis (n = 29)

In 13 of 29 patients, the arthritis consisted of noninfectious inflammation in one or more joints. This included gout, severe progressive osteoarthritis, necrosis of the head of the femur, reactive arthritis in response to Crohn's disease and intestinal
infection, paraneoplastic polyarthritis and seronegative symmetric polyarthritis. Those joints showed an increased accumulation on $^{111}$In-IgG scintigraphy but with a different distribution pattern compared with septic arthritis as seen in five other patients. In infectious arthritis, diffuse, intense uptake is seen in the joint, whereas in sterile arthritis typically the synovial lining is visualized.

In two of seven patients with $^{111}$In-IgG scintigraphy scored positive for infection, and no septic arthritis could be proven ("false-positives"). Histologic specimens from both joints (knee and ankle) showed mild, chronic synovitis. No signs of infection could be detected in all nine patients with normal uptake of $^{111}$In-IgG in their joints.

**Soft-Tissue Infection (n = 7)**

The soft-tissue infections consisted of abscess in the psoas muscle region (n = 2), abscess in the thigh (n = 2), abscess in the calf (n = 1) and infection in a Girdlestone hip (n = 2). Six infections were proven by culture and histology and showed increased $^{111}$In-IgG uptake on scintigraphy, including two patients with acquired immunodeficiency syndrome and one patient with leukopenia due to chemotherapy. One Girdlestone hip with a negative $^{111}$In-IgG scintigram was proven to be noninfected by surgically obtained culture.

**Spondylodiscitis/Vertebral Osteomyelitis (n = 16)**

Spondylodiscitis was proven twice by puncture (lumbar spine), culture revealed *Kingella denitrificans* and *kingae* (Fig. 3). Both patients showed focal $^{111}$In-IgG accumulation on scintigraphy. In 13 patients with negative $^{111}$In-IgG scintigraphy no spondylodiscitis was detected by long-term follow-up. In one patient blood cultures revealed *Brucella* species, after which antibiotic therapy was started, 4 days before scintigraphy. $^{111}$In-IgG scintigraphy showed no increased uptake. MRI showed at this time only early epiduritis, no spondylitis, while on CT no signs of infection were seen. Lumbar puncture revealed an acute infection of the central nervous system. Doxycycline (1 dd 200 mg) and rifampicin (1 dd 100 mg) was continued for 4 mo. Two and 5 wk later MRI showed both epiduritis and spondylitis at L3–L4. $^{111}$In-IgG scintigraphy was scored as false-negative.

**Technetium-99m-MDP Bone Scintigraphy**

The results of $^{99m}$Tc-MDP bone scintigraphy are summarized in Table 2. In all but one patient category, this imaging technique showed an excellent sensitivity. In the patient with false-negative $^{111}$In-IgG scintigraphy for spondylitis the $^{99m}$Tc-MDP bone scintigraphy also was false-negative. Specificity of $^{99m}$Tc-MDP bone scintigraphy for osteomyelitis is considerably lower than sensitivity.

**DISCUSSION**

This study shows that $^{111}$In-IgG scintigraphy is a very sensitive imaging technique for evaluating infection of the locomotor system. In most patient categories the sensitivity for infection was optimal, only one patient with spondylitis in the lumbar spine did not show increased $^{111}$In-IgG accumulation on scintigraphy. Specificity varies between different patient categories. Specificity is high in patients with total hip arthroplasty, chronic osteomyelitis, arthritis, soft-tissue infection and spondylodiscitis (82%, 93%, 82%, 100% and 100%, respectively), moderate in patients with total knee arthroplasty and diabetic foot pathology (50% and 67%) and low in patients with pseudarthrosis (11%). The high negative predictive value is important for planning, e.g., in prosthesis revision, given the significant extra time and costs of adequate infection treatment. In all foci, scored as false-positive with $^{111}$In-IgG scintigraphy, signs of sterile inflammation were present. This confirms the present concepts of the mechanism of $^{111}$In-IgG accumulation being not specific for infection but occurring in any inflamma-

![FIGURE 3. Indium-111-IgG scintigram of a 35-yr-old male patient with low back pain. Focal $^{111}$In-IgG accumulation is seen on the ventral side of the vertebra L3–L4. Biopsy of the vertebra L3–L4 proved infection (K. denitrificans).](image-url)
tor focus (8,10). In all categories, though, specificity of 111In-IgG scintigraphy is higher compared with 99mTc-MDP scintigraphy. Indium-111-IgG does not, like 99mTc-MDP, accumulate in metabolic active bone. Therefore, previous pathologic changes of the bone, like arthroplasty and chronic osteomyelitis, compromise image interpretation of 111In-IgG scintigraphy less than 99mTc-MDP scintigraphy.

Comparing cemented with cementless total hip arthroplasties shows that the period for 111In-IgG scintigraphy to become negative after arthroplasty is considerably longer for cementless total hip arthroplasty. Noninfected cemented total hip arthroplasties showed no increased 111In-IgG uptake scintigraphy from 6 wk after implantation, whereas all but one noninfected cementless total hip arthroplasty showed false-positive 111In-IgG accumulation on scintigraphy when recorded within a 14-mo period after arthroplasty. Therefore, differentiation between cemented and cementless total hip arthroplasty is important for image interpretation of 111In-IgG scintigraphy in the first year after arthroplasty. Persisting accumulation around uncemented prostheses also holds true for 111In-labeled leukocyte scintigraphy, as shown by Oswald et al. (11). Their study showed increased 111In-labeled leukocyte uptake on scintigraphy up to 2 yr after implantation of cementless total hip arthroplasties. Wegener and Alavi hypothesized that ingrowth of bone and fibrous tissue in the porous coating of the cementless prosthesis caused this prolonged uptake of the tracer on scintigraphy (1).

Periarticular ossification and debris formed by polyethylene socket wear, both clearly visualized on plain radiography, are other causes of sterile inflammation after total hip arthroplasty and focal-increased 111In-IgG uptake on scintigraphy (10). However, in most cases, image interpretation does not need to be impaired when the 111In-IgG images are read in conjunction with radiographs. Despite our impression that nonbone-marrow uptake of 111In-IgG around the neck of the femoral component of a hip arthroplasty (outside the osseous structures) could be caused by such noninfectious reaction after socket wear, the scintigraphy was scored positive, since uptake was clearly elevated. Only 3 of 7 total hip arthroplasties proved to be infected when this pattern of 111In-IgG uptake was seen.

Due to the high prevalence of noninfectious inflammation after total knee arthroplasty, the specificity of 111In-IgG scintigraphy is relatively low in this patient category. It seems possible to increase this specificity to 71% by differentiating between increased 111In-IgG uptake on scintigraphy around the knee arthroplasty due to noninfectious inflammation of soft tissues (horseshoe shaped, mild uptake in the suprapatellar bursa above the prosthesis) and uptake due to infection of the knee arthroplasty itself (diffuse uptake, also located in bone). Persistent periprosthetic 99mTc-MDP uptake for several years like in total hip arthroplasties limits the role of this scintigraphic technique in total knee arthroplasties even more (12). Little has been reported on other scintigraphic imaging techniques of knee arthroplasty. One study reported a 95% accuracy of combined leukocytes and sulfur colloid imaging in these patients (13).

These results are in accordance with a previous study that showed that 111In-IgG scintigraphy is very accurate for evaluating chronic osteomyelitis (10). Controversy exists about the usefulness of leukocyte (neutrophil)-labeled scintigraphy in diagnosing chronic osteomyelitis, with predominant infiltration of mononuclear cells (2,14). As stated above, previous pathologic changes of bone-like chronic osteomyelitis do not reduce specificity of 111In-IgG scintigraphy. Not surprisingly, specificity of 99mTc-MDP scintigraphy is considerably lower in this group of patients (55% versus 93%).

It was difficult to distinguish infection in soft tissue from osteomyelitis with 111In-IgG scintigraphy, particularly in diabetic foot patients with deep ulcers on the heel and in patients with decubitus and a deep fistula. Although bone scanning is essential for localizing osseous structures, separating bone from soft-tissue infection was not possible in these patients. As indicated by Ezuddin et al., SPECT imaging may be helpful to differentiate these two conditions (15). The ability of MRI to separate bone from soft-tissue infection is a major advantage of this technique for diagnosing osteomyelitis in diabetic foot patients. Yuh et al., in a study of 24 diabetic foot patients, found a specificity 100% of MRI for osteomyelitis (16). Indium-111-labeled leukocyte studies as well reported good results in this patient category, although sensitivity and specificity varied from 79% to 100% and from 68% to 95%, respectively (17-19). A Charcot joint with a recent fracture can be the cause of a false-positive result of 111In-IgG scintigraphy, as was reported in an earlier study of 16 diabetic foot patients (20).

Specificity of 111In-IgG scintigraphy for infection in pseudarthrosis is very low (11%). Nepola et al. reported an 82% (59/70) specificity of combined labeled leukocyte and bone scintigraphy for infections of delayed unions or nonunions (21). Their explanation for the false-positive results in unstable fractures was that these were caused by continued irritation from motion at the unstable sites. This is probably true as well for the nonspecific 111In-IgG uptake on scintigraphy in pseudarthrosis.

Indium-111-IgG scintigraphy visualizes septic arthritis as well as noninfectious inflammatory pathology of the joints, such as metabolic, reactive and autoimmune arthritis. As indicated above, in most patients, the pattern of 111In-IgG uptake on scintigraphy is different for septic and noninfectious inflammatory arthritis. Detailed clinical information is helpful for a correct image interpretation of 111In-IgG scintigraphy of these patients. An advantage of the use of this and other radiopharmaceuticals in the detection of (poly-)arthritis activity is that it allows direct imaging of joints by means of whole-body scintigraphy and of joints that are difficult to assess clinically or radiographically (22).

The true-positive-scored 111In-IgG scintigraphy in this study of three immunocompromised patients (AIDS and leukopenia due to chemotherapy) with soft-tissue infections confirm that it is possible to detect infections in these patients with this imaging technique (6,23). Because these patients are very susceptible to infection and infection often presents atypically in these patients, reliable diagnostic techniques are needed. Some disagreement exists over whether labeled leukocyte scintigraphy is sensitive enough for this purpose (14,24).

The only case of bone infection missed by 111In-IgG scintigraphy in this study concerned a patient with early, low-grade spondylodiscitis. Lower sensitivity for osteomyelitis of the spine has been reported in studies using other scintigraphic techniques as well, including labeled leukocyte and 99mTc-IgG scintigraphy (25-28). Modic et al. reported a 96% sensitivity using MRI to detect vertebral osteomyelitis (29). MRI is more useful than CT scanning in this group of patients because it provides better anatomic detail and can differentiate between vertebral and soft-tissue infections (30,31).

**CONCLUSION**

Indium-111-IgG imaging is a sensitive technique for evaluation of infections and inflammatory bone and joint disease. Specificity is increased over 99mTc-MDP bone scintigraphy, which in most cases is the first procedure performed on these patients except for those with recently violated bone. Specificity of 111In-IgG scintigraphy for infection can be increased even
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REFERENCES


