DIAGNOSTIC NUCLEAR MEDICINE

The Appearance of Bone Scans Following Fractures, Including Immediate and Long-Term Studies

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Bone scans were performed on 204 patients at intervals ranging from 6 hr to several years after traumatic fractures. The minimum time for a bone scan to become abnormal following fracture was age-dependent; however, 80% of all fractures were abnormal by 24 hr, and 95% by 72 hr, after injury. Three distinct temporally related phases were noted on bone scans as sequential studies showed a gradual return to normal. The minimum time for a fracture to return to normal on a bone scan was 5 mo. Approximately 90% of the fractures returned to normal by 2 yr after injury.

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Bone scans performed with technetium-99m phosphate compounds have proven to be among the most useful nuclear medicine procedures. The bone scan provides a sensitive method of detecting primary and metastatic skeletal neoplasms, and it has been useful in evaluating metabolic bone disease and various joint abnormalities (*1–8*). Although the procedure is helpful in evaluating skeletal trauma (*9–12,14*) little information is available about how bone scans change in appearance following fracture, and there have been essentially no long-term studies.

Clinical experience has shown that the bone scan can be used to tell a recent fracture from a healed fracture. However, information is limited for more specific questions, such as how the pattern of radioactive uptake changes with time, and how soon the scan of a fracture site returns to normal. This paper addresses these specific questions.

MATERIALS AND METHODS

Bone scans were performed on 204 patients with various types of fractures. The patients were studied in the acute, subacute, and healing stages. The acute studies were performed within 2 wk after fracture, including 60 patients who had bone scans within the first week of injury. The studies on these patients were performed until their fractures became abnormal or until 7 days after injury. In this group, nine patients were studied within 6 hr of their injury, and 20 within 24 hr.

The subacute studies were performed during the interval from 4 wk to 4 mo after injury; and the long-term or healing-stage studies were performed at periods varying from 6 to 36 mo after fracture. A group of 102 of the patients had serial studies, including at least one bone scan in each of the acute, subacute, and healing stages.

In addition, all patients who had bone scans for any reason were questioned about fractures they had incurred in the past. Several patients had suffered fractures more than 40 yr before their bone scan.

All patients included in the study had definite evidence of fracture on radiograph, although in some cases the bone scan was found to be abnormal before the radiologic diagnosis of fracture. Patients with only "periosteal" or other radiographic findings that were merely suggestive of fracture or "stress" fracture were not included. All fractures were treated in the standard manner of reduction and immobilization for the required amount of time.

Forty-two patients with open reductions, or whose treatment involved the insertion of orthopedic fixation

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devices, were included in the study in a category separate from those who had closed reductions. The former also had delayed studies, which were analyzed in a manner similar to that of the closed-reduction group.

Male and female patients were present in approximately equal numbers in the study, and the age range was from 17 to 88 yr. Approximately one third (65) of the 204 patients were under 35 yr of age, one third (72) were between 35 and 65, and the remaining third (67) were over 65. The sex and age ratios were also approximately the same in the group of patients studied within a week of fracture, in those who had serial studies, and in the open-reduction group.

Although many types of fractures were examined, we studied mainly patients with vertebral compression fractures, rib fractures, and fractures of the distal extremities. The group of 204 patients included 60 with fractures of the long bones, 47 had rib fractures, 45 had vertebral fractures, and 42 had miscellaneous traumatic fractures, such as clavicular, scapular, wrist, and head injuries. The age distribution in each group was also approximately equal, with one third being under 35, one third between 35 and 65, and one third over 65. The only exception was in the vertebral compression group, in which a larger percentage of the patients were over 65 years of age.

All patients were studied with Tc-99m phosphate compounds and a scintillation camera equipped with a high-resolution collimator. The earlier studies were performed with Tc-99m disodium etidronate or pyrophosphate, while more recent follow-up studies used Tc-99m methylene diphosphate. Polaroid scintiphotos were obtained of the fracture site, of a contralateral control area, and of normal ipsilateral adjacent bony structures. All studies were performed 4 hr after injection and were analyzed visually for the distribution and intensity of activity in the vicinity of the fracture. Clinical and roentgenographic correlation was performed in all cases.

RESULTS

As Table 1 shows, of the 20 patients with closed fractures studied with bone scans within 24 hr of fracture, 16 had abnormal bone scans. Of the four normal studies, three were on patients over 65 yr of age, including two with fractured hips and one with a vertebral compression fracture. The fourth patient with a normal study was a 10-year-old boy with a compression fracture of the third cervical vertebra. His immobilization apparatus made this initial bone scan less than optimal in quality.

Although 80% of the patients had abnormal studies within 24 hr, 95% of those under 65 yr of age showed increased activity at the fracture site within a day after injury.

TABLE 1. TIME AFTER FRACTURE FOR BONE SCAN TO BECOME ABNORMAL

Time after fracture	Patients studied	No. with abnormal scans	% abnormal	% abnormal under age 65
1 day	20	16	80	95
3 days	39	37	95	100
1 wk	60	59	98	100

Thirty-seven of the 39 patients of all ages studied within 3 days of injury had abnormal bone scans at the fracture site. The two whose studies were not abnormal by 72 hr were both over 65. Only one patient—an 80-year-old woman with osteoporosis and an impacted hip fracture—did not demonstrate an abnormal bone scan by 1 wk after her injury. All of the remaining 59 studies performed 1 wk after injury were abnormal.

Many of the older patients had hip fractures. They were usually in pain, and a few of them were unable to empty their bladders adequately. The resultant bladder activity could have impaired early detection of abnormalities in this group. We attempted to overcome this difficulty with delayed views and bladder catheterization.

Sequential bone scans performed on the group of 102 patients at intervals up to 36 mo after injury showed three rather distinct phases. The first phase, (acute stage) persisted for about 3–4 wk after injury. It was characterized by a diffuse area of increased activity surrounding the fracture site. A distinct fracture line was frequently seen during this stage.

The second phase (subacute stage) was characterized by a well-defined linear abnormality at the site of the fracture. This stage lasted about 8–12 wk and showed the most intense uptake at the fracture site.

The third phase (healing stage) was characterized by a gradual diminution in the intensity of the abnormality until the scan returned to normal. Figure 1 gives an example of the three stages in a 29-year-old woman who was thrown from a horse, suffering a compression fracture of the first lumbar vertebra. Her first scintiphoto, obtained 24 hr after injury, shows a rather diffuse area of increased activity in the superior aspect of L-1. The second scintiphoto, obtained at 2 mo, shows an intense, well-defined band of increased activity at the fracture site. The third scintiphoto was obtained at 6 mo and demonstrates the gradual decrease in activity typically noted in the healing stage. The final scintiphoto, obtained 9 mo following her injury, is completely normal. In many patients, as shown in Table 2, the healing stage of vertebral fractures lasted many months, with only 59% of the patients achieving normal bone scans 1 yr after injury.

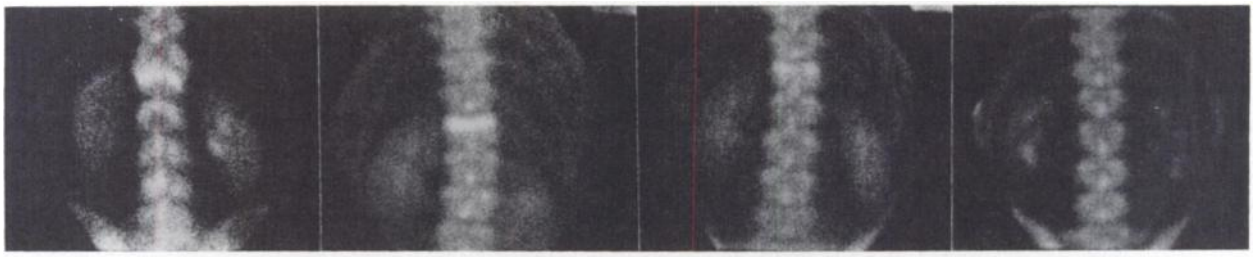

FIG. 1. Stages of healing in 29-year-old female with compression fracture of first lumbar vertebra. Initial scintiphoto was performed 24 hr after injury; others were obtained at 2, 6, and 9 mo. Scintiphoto returned to normal by the 9-mo study.

Table 2 summarizes the long-term data. It shows the number and percentage of bone scans in patients with closed or nonmanipulated fractures that had become normal at the fracture site at 1, 2, and 3 yr after injury, and also shows the minimum time for return to normal in each type of bone. By 2 yr after injury ~90% or more of the fractures had returned to normal. Rib fractures showed the most rapid healing, with almost 80% of the scans normal by 1 yr after injury.

Figure 2 gives an example of the typical scintiphoto appearance of a rib fracture. The first image shows a right posterior rib fracture in a 60-year-old man 1 mo after injury. Rib fractures almost always appear as a focal, intense region of increased activity superimposed upon the rib outline. We used lateral and oblique views, as well as standing and recumbent images, to differentiate between delayed renal excretion and rib fractures. The second scintiphoto was obtained 1 yr after injury. It is normal, demonstrating complete healing of the fracture.

The bone scans on the 42 patients who required open reduction of their fractures, or in whom orthopedic fixation devices were inserted, remained abnormal for a considerably longer time than those with simple reductions. The studies on this group also appeared to have three distinct phases, but the time course of each was more prolonged. By 3 yr after fracture, less than 50% had returned completely to normal.

Surprisingly, three patients who had simple fractures with simple reductions more than 40 yr before their bone scans showed an abnormality at the fracture site. In all three cases, the abnormality was asymptomatic and located in a long bone. Here the abnormality was an incidental finding, detected during total-body bone scans for possible metastatic disease, and in all three, radiographs of the areas showed no evidence of fracture.

In general, the time for an uncomplicated fracture to return to normal on a bone scan appeared to depend on the age of the patient, with the older patients showing a greater delay. However, about 90% of all fractures of the vertebrae, distal extremities, and ribs were normal by 2 yr after injury, and over 95% were normal by 3 yr.

DISCUSSION

Marty (*1*), Fordham (*9*), and Rosenthall (*10*) in their reviews of bone scans soon after fracture found, as we did, that fracture scans can appear abnormal as early as a few hours after injury. Our data showed that 95% of the patients under 65 yr of age had abnormal bone scans by 24 hr after injury, and that 95% of all patients, regardless of age, had abnormal scans by 72 hr. This indicates that it would be helpful, in cases of questionable fracture, to perform a bone scan within a day or two after injury.

The difference between the older patients and those under 65 in the rapidity of the appearance of abnormality on bone scans, as well as the tendency to a more delayed return to normal, is probably due to factors associated with healing. Rosenthall and Kaye (*13*), in their review of the mechanisms of labeled phosphate complex in metabolic bone disease, showed that there is no significant difference in the 5-hr bone-to-soft-tissue ratios of Tc-99m (Sn)pyrophosphate in osteoporotic patients when compared with controls. Although quantitative bone labeling factors may be the cause of the difference,

TABLE 2. BONE SCANS NORMAL AGAIN AT FRACTURE SITE

	No. studied	Normal at 1 yr	Normal at 2 yr	Normal at 3 yr	Minimum time to normal
Vertebrae	32	19 (59%)	29 (90%)	31 (97%)	7 mo
Long bones	22	14 (64%)	20 (91%)	21 (95%)	6 mo
Ribs	28	22 (79%)	26 (93%)	28 (100%)	5 mo
Miscellaneous	20	12 (60%)	18 (90%)	19 (95%)	6 mo

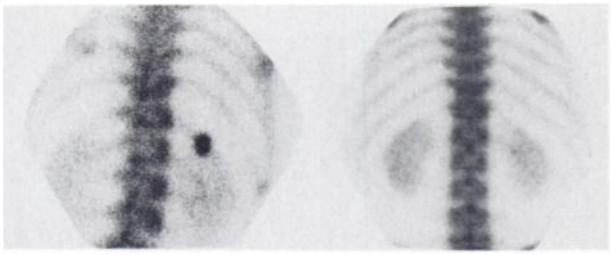

FIG. 2. Bone scans performed 1 mo and 1 yr following posterior fracture of right 11th rib in 60-year-old man. Note focal and intensely abnormal appearance of fracture. Scan has returned to normal at 1-yr study.

their finding makes this possibility somewhat less likely.

As previous discussions on skeletal trauma have noted, increased activity on a bone scan can be due to soft-tissue injury as well as osseous injury. High-resolution images, correlation with roentgenograms, and experience can help to differentiate between soft-tissue and osseous injury. In cases of doubt, a repeat bone scan after a few days will usually provide the answer. Soft-tissue trauma usually subsides within a few days, whereas skeletal injuries continue to be very prominent.

The changing bone-scan appearance of fractures with time is an interesting phenomenon, and is probably related to the healing process itself. The initial rapid uptake in and around the fracture site is most likely due to increased blood flow in the area of the injury. As callus forms during the ensuing days and weeks, the bone scan shows a more localized "fracture line," as well as a more distinct separation of the abnormality from the surrounding normal bone (*14*). We can postulate that the subacute stage of healing, i.e., the period a few weeks after injury, shows the most intense tracer uptake because the physiologic repair process is most active at this time. It probably results from a continuing increase in blood flow with respect to surrounding tissues as well as an active osteoblastic repair process.

The slow resolution of the abnormality at the fracture site probably reflects the diminishing physiologic activity as the new bone becomes indistinguishable from the adjacent osseous tissue. It is understandable that fixation devices such as orthopedic screws or rods can cause a delayed return of a bone scan to normal, but why should a simple fracture show a continuing abnormality decades after the injury? Fortunately, examples of this extreme delay following simple fractures are quite rare and will hardly ever cause confusion in clinical interpretation. However, the fact that fractures can be seen, albeit rarely, for many years after injury reinforces the need to obtain a good history from patients being studied with bone scans.

In general, almost all simple fractures will have returned to normal on bone scan by 2 yr after injury. Although only 59% of vertebral compression fractures in patients of all ages will have returned to normal by a year after injury, 90% will be normal at 2 yr, and 97% will be normal on 3-yr scans. We have found this information helpful in making the differential diagnosis between compression fractures and metastatic disease in patients with breast or prostate carcinoma, or with other tumors having a predilection for skeletal metastasis. Metastatic disease becomes the much more likely diagnostic probability in a tumor patient if a vertebral abnormality is noted 2 or 3 yr after injury.

The appearance of the scan lesion can also be quite helpful in making a differential diagnosis. The most intensely abnormal lesions on bone scans include skeletal carcinoma, both primary and metastatic, Paget's disease, and fractures in the subacute or early healing phases. Arthritis, benign bone lesions, and fractures in the late healing phase are almost always less intensely abnormal on the scintiphoto. In addition, fractures are usually seen as focal areas of uptake (e.g., the rib fracture shown in Fig. 2), whereas rib or other metastases become more elongated or diffuse. Paget's disease is rarely detected as a solitary focal lesion on bone scans; it is most commonly seen as a more or less widespread abnormality spreading out in a diffuse pattern in the pelvis, skull, spine, and long bones. The abnormality on the scintiphoto is usually considerably more impressive than the patient's symptoms, and the pattern is almost always easily differentiated from the more focal appearance of a fracture.

In many cases, correlation with good-quality radiographs will help provide the correct diagnosis.

SUMMARY

In a study of the appearance of bone scans following fracture, we found that 95% of all fractures gave abnormal scans within 72 hr of injury, and that 80% were abnormal within 24 hr. We also found that bone scans had three phases, which were temporally related to the injury. In the acute phase (first 3–4 wk), the scans showed a generalized diffuse increase in radioactivity about the fracture site. The abnormality became more localized and intense in the subacute phase (2–3 mo). The healing phase was characterized by a gradual decline in radioactivity at the fracture site until it was indistinguishable from surrounding bone. In this series, the return of the fracture site to normal occurred as early as 5 mo after injury, and 90% of scans of fractures treated without manipulation or by closed reduction returned to normal by 2 yr after injury. Advanced age was associated with both a delay of onset as well as a delay of resolution of scan abnormalities.

Patients requiring open reduction or the insertion of orthopedic fixation devices can show increased radionuclide activity at the fracture site for considerably

longer than the patients who do not require surgery.

The bone scan can also be used to help detect fractures that are difficult to diagnose by radiograph, such as navicular fractures. The technique can also be helpful in fractures of the hip, especially in older osteoporotic patients. In this group of patients, however, the study is often not dependable until 72 hr after injury.

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