TIME-DEPENDENT IMAGE QUALITY USING ^{99m}Tc-PYROPHOSPHATE

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Technetium-99m-labeled pyrophosphate has proved to be a useful skeletal-imaging agent. In this study, specific areas of the skeleton were imaged at times ranging from ½ to 6½ hr after injection of ^{99m}Tc-pyrophosphate. Count ratios between abnormal and normal bone with respect to adjacent soft tissue were obtained for selected regions of interest on computer-stored scintillation camera images. The results show that image quality improves most rapidly from ½ to 2 hr, but further modest gain in quality does occur on views recorded between 2 and 6 hr. All lesions detected on the later images were also observed on the early ones and the ratios of uptake between abnormal and normal bone from computer-processed scintillation camera images did not change appreciably with time after the ½-hr images. Our results confirm the clinical impression that overall image quality is better on views obtained at least 3 hr after injection. Further delays in imaging beyond 3–4 hr after injection probably will not result in any appreciable gain in diagnostic accuracy.

Bone scans of consistently good quality are obtained with ^{99m}Tc-pyrophosphate. The time interval between injection of the radionuclide and the recording of images that results in satisfactory skeletal detail with acceptably low soft-tissue activity is 3–4 hr (*1–3*). Weber, et al (*2*) observed that after admininistration of ^{99m}Tc-pyrophosphate, the quality of the scintillation camera images appeared to improve with time and was best at 5–6 hr after injection. Our study was undertaken to quantify image quality with respect to imaging time.

MATERIALS AND METHODS

Fifteen patients who had been referred to the Nuclear Medicine Division for bone scans to evaluate the presence of metastatic disease were included in this study. Fifteen millicuries of ^{99m}Tc-pyrophosphate (PhosphoTec, supplied by E. R. Squibb & Sons, Inc.) was administered intravenously to each patient. Binding efficiency was determined for each preparation by paper chromatography and the pH of each preparation was measured. In order to determine the clearance characteristics of the ^{99m}Tc-pyrophosphate, blood specimens were collected at ½, 1, 2, 3, and 4 hr after injection of the radionuclide and urine samples were collected throughout the study. An SMA-12 serum chemical profile was obtained on each patient before examination. Medical records were reviewed and previous radiographs were evaluated for all known and suspected areas of metastasis.

A rectilinear bone scan was performed on all patients 3–4 hr after administration of the radiopharmaceutical. Five patients were imaged on a scintillation camera (Searle Radiographics HP Pho/Gamma Camera) at ½ and 2 hr after injection, five patients at 2 and 4 hr, and five patients at 4 and 6 hr (Fig. 1) with simultaneous recording of images on magnetic disk and Polaroid film. Scintillation camera images were subjectively assessed for image quality and the corresponding images that had been stored on magnetic disk were analyzed by means of a computer (Medical Data Systems Corp., Modumed Trinary System) to establish activity ratios between (A) normal bone and soft tissue, (B) abnormal bone and soft tissue, and (C) abnormal and normal bone.

The method used for evaluation of computer-stored images for quality, i.e., the ratio of counts in bone (whether normal or abnormal) to counts in soft tissue is shown in Fig. 2. Specific regions of

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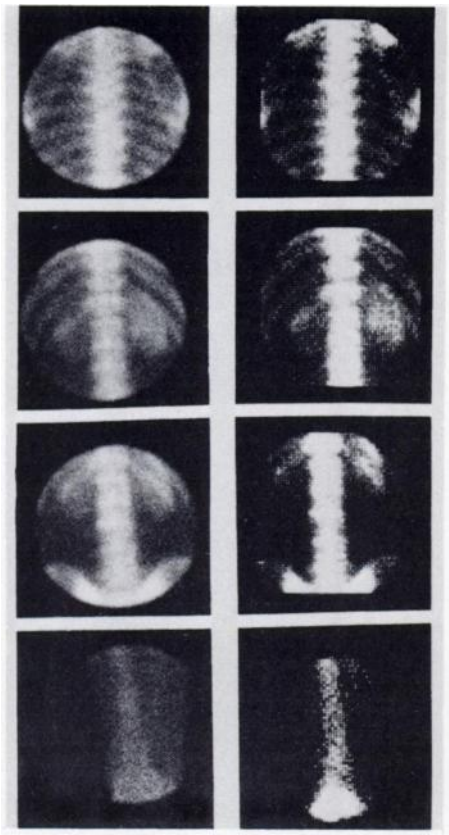

FIG. 1. Conventional scintillation camera images (left column) and computer-processed scintillation camera images (right column) obtained 4 hr after administration of ^{99m}Tc-pyrophosphate. Images include ribs, vertebrae, and femoral shaft. On each patient two sets of images were obtained that included these views in addition to those of clinically symptomatic areas or abnormal scan sites.

interest on each set of serial scintillation camera images were identified by means of the computer. The average count rate per channel was derived, and the ratios between abnormal bone and adjacent soft tissue, between normal bone and soft tissue, and between abnormal and normal bone were generated. The count ratio between normal bone and soft tissue was plotted for two specific areas; the right femur and the thoracolumbar spine (Fig. 3). All abnormal areas were compared with adjacent normal areas of similar size and the results tabulated with respect to time (Table 1). In addition, the area over the liver was flagged and compared with a similar area on the contralateral side.

RESULTS

Reproducible binding efficiencies of more than 95% and pHs in physiologic ranges were observed for all ^{99m}Tc-pyrophosphate preparations. Blood and urine clearance rates were similar to those reported previously by Weber, et al (*2*). An increased concentration of radioactivity was visualized on rectilinear scans in the thyroid region in all patients and in the liver in two patients. One patient demonstrated a mildly elevated alkaline phosphatase that did not seem to affect the quality of her study. Clinical chemistries were normal in the other patients.

The image quality of the rectilinear scans was good to excellent. The scintillation camera images recorded 2 hr or more after injection of the radionuclide were of good to excellent quality but the images obtained at ½ hr were considered to be of only fair quality. The images recorded at 4–6 hr after injection consistently demonstrated better anatomic detail and definition of lesions than were seen on the earlier images. This was observed despite generally reduced counting statistics on the later images; typically, two-thirds as many counts were collected on the second set of images.

Five of the 15 patients revealed metastatic lesions on the radiographs and all of these lesions were detected by each scanning modality. In addition, two patients had abnormal bone scans in areas which were radiographically normal.

Computer quantification of activity in the femur and the thoracolumbar vertebrae indicated that the ratio of normal bone to soft tissue increased rapidly from ½ to 2 hr and then more slowly from 2 to 6 hr (Fig. 3). The ratio of radioactivity in abnormal to normal bone remained relatively constant for paired serial images.

DISCUSSION

Computer analysis of digitized camera images confirmed the clinical impression that image quality progressively improves during the first 5–6 hr after administration of ^{99m}Tc-pyrophosphate. The ratio of radioactivity between abnormal and normal bone, however, did not increase for paired serial images up to 6 hr after injection. This finding is consistent with the clinical observation that although improved lesion detail was evident in later images, no new lesions were identified. Our results suggest that imaging beyond 3–4 hr after administration of ^{99m}Tc-

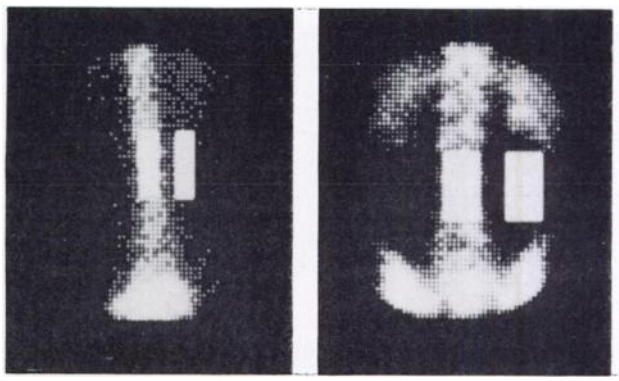

FIG. 2. Method of "flagging" normal bone and adjacent soft tissue for femur and thoracolumbar spine.

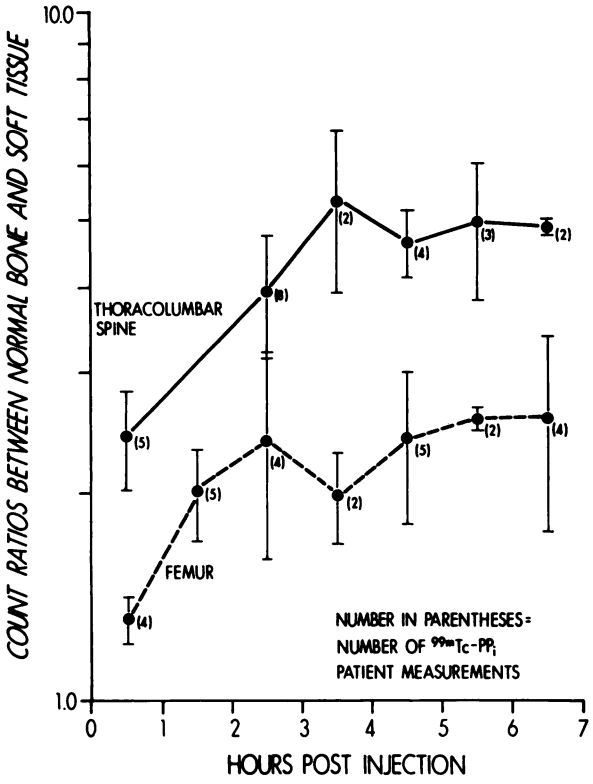

FIG. 3. Normal bone-to-soft-tissue count ratios for femur and thoracolumbar spine. Graph shows average ratios for hourly periods over first 7 hr after injection. Two sets of images spaced by minimum of 1 hr were obtained in 13 patients for femoral determinations and in 12 patients for thoracolumbar spine determinations.

pyrophosphate will not improve diagnostic accuracy. As early as 2 hr after injection, the ^{99m}Tc-pyrophosphate preparation used in this study provided very good images with each of the imaging techniques used. As reported in earlier studies, the bone scan appeared more sensitive than conventional radiography in detecting metastatic lesions (*4–7*). All lesions demonstrated radiographically were detected by each of the imaging procedures. Two patients with normal radiographs in selected regions were found to have abnormal bone scans compatible with metastatic disease.

Although free pertechnetate ($^{99m}TcO_4^-$) was observed chromatographically in only one preparation, the observation of radionuclide uptake in the regions of the thyroid and salivary glands on all of the rectilinear scans suggested that a small amount of free $^{99m}TcO_4^-$ was present routinely in vivo. The authors have noted the similar concentrations of activity with both ^{99m}Tc-polyphosphate and ^{99m}Tc-diphosphonate. Increased deposition of the bone-imaging agent (^{99m}Tc-diphosphonate) in the tracheal cartilage might be an alternate cause of uptake in the region of the thyroid (*8*).

The increased uptake in the liver observed in two patients may relate to the release of some of the ^{99m}Tc label from the pyrophosphate in vivo, with formation of other reduced forms of ^{99m}Tc that are metabolized in the liver. Increased amounts of the stannate form of tin (*9*) or high pyrophosphate concentrations (*10*) can also result in increased accumulation in the liver, spleen, and bone marrow. Thrall, et al (*11*) and Charkes, et al (*12*) have reported that the liver is routinely observed on rectilinear scans done with ^{99m}Tc-polyphosphate. Our lesser incidence of liver visualization suggested that the pyrophosphate preparation used here minimizes this nontarget activity.

Six of the patients in this study had previously diagnosed breast carcinoma and had undergone radical mastectomy from 6 weeks to 6 years before the scan procedure. In each patient the rectilinear scan revealed diffuse increased activity in the region of previous surgery that is attributed to modified vascular structures and the lack of tissue absorption from the excised breast. Previous reports have shown that ^{99m}Tc-labeled phosphorus-containing compounds concentrate in normal as well as cancerous breast tissue (*13–15*), and in soft tissue after radical mastectomy (*16*).

TABLE 1. ABNORMAL-TO-NORMAL BONE AND ABNORMAL BONE-TO-SOFT-TISSUE RATIOS IN VIVO

		Hours after injection							
		½		2		4		6	
Patient	Lesion site	Abn/NI	Abn/ST	Abn/NI	Abn/ST	Abn/NI	Abn/ST	Abn/NI	Abn/ST
AF-2	Lumbar spine	—	—	2.1	5.9	1.7	5.8	—	—
LJ-4	Thoracic spine	1.3	2.7	1.4	3.1	—	—	—	—
EB-5	Thoracic spine	1.5	2.8	1.6	4.5	—	—	—	—
PF-6	Lumbar spine	1.8	3.9	1.7	6.0	—	—	—	—
SR-7	Lumbar spine	1.3	2.7	1.3	4.0	—	—	—	—
	Femoral head	1.5	3.4	1.6	6.1	—	—	—	—
LM-12	Lumbar spine	—	—	—	—	1.8	8.4	1.8	8.7
	Thoracic spine	—	—	—	—	1.4	6.3	1.5	6.1

Abbreviations: Abn/NI, abnormal-to-normal bone ratio; and Abn/ST abnormal bone-to-soft-tissue ratio.

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