WHOLE-BODY GAMMA CAMERA IMAGING USING A MOVING TABLE ACCESSORY

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The characteristics of a scintillation camera system for whole-body imaging are described. The advantages of decreased imaging time, reduced patient discomfort, and the ready intercomparison of different body areas on the same Polaroid film are presented.

Radiographical skeletal survey has been widely used to detect bony metastasis preoperatively. The ability of the radiographic method to detect bony lesions depends on the change of bony density which in turn depends on the amount of calcium content. A change of 30–75% of osseous content must be present before it can be seen on radiographs. The radiographic method is especially insensitive for cancellous bones (*1–3*). It is therefore hazardous to rely solely on the radiographic approach as an adequate method for early detection of bone metastasis.

On the other hand, it has been well established that scanning is a much more sensitive method than radiography in the early detection of bone lesions (*4–11*). This occurs because the radionuclide imaging depends on the local metabolic rate of bone which depends on local blood flow and pathological invasion as well as the repairing process.

In the past, the use of bone scanning has been limited to patients with proven malignancy because of the high radiation dose from the most commonly used radionuclide ^{85}Sr. Recently, new bone-scanning agents such as ^{18}F, ^{99m}Tc-polyphosphate (Tc-PP) and ^{99m}Tc-diphosphonate have become commercially available. These have reduced the radiation dose significantly and produced improved images. Moreover, the average total-body dose for ^{99m}Tc-polyphosphate scan is now lower than the average radiation dose for a routine skeletal radiographic bone survey (*12*). A disadvantage of the isotope bone survey by gamma camera has been the limited field of view and the need for multiple, independent images. A few whole-body scanning systems with minification have been introduced and are available commercially but they are slower. The purpose of this paper is to evaluate the capability of a recently introduced moving table whole-body imaging system (Picker Omniview used with Dyna Camera 2C) based on a concept proposed by Cooke and Kaplan (*13*), which includes a gamma camera electronically interfaced to a moving table device. An entire 7 × 2-ft skeletal image can be recorded on a single Polaroid film and simultaneously recorded on magnetic tape for replay at any of four magnifications for detailed regional evaluation.

METHODS AND MATERIALS

The whole-body imaging system evaluated was a hybrid scanning camera. The object to be imaged was placed on a moving table which moved linearly. The image on the oscilloscope was moved proportionally to the table which decoded the image for recording on film. In this study Polaroid film was used. The evaluation of the moving table was done by comparing images of moving and nonmoving modes of operation.

The parameters of evaluation were the normal camera performance criteria: uniformity, linearity, resolution, and image quality. Each study was done with equivalent statistics to produce an equitable comparison. Uniformity was imaged with a commercially available Lucite volume source 13 in. in diameter actuated with 3 mCi of ^{99m}Tc in water. The 1K information density phantom used was Teflon tubing mounted on 2-in. centers on Masonite pegboard. Two mCi of ^{99m}Tc were injected into the tubing grid. The 1K information density exposure control

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was used in both images. For resolution, images of a lead bar phantom placed between the collimator and the volume source were obtained. To evaluate changes between moving and nonmoving images, the highest resolution collimator was used (26,000-hole ultra-fine collimator) and high statistics were collected (4K information density) to visualize best the smallest bars.

The lead bars were rotated 45 deg so that they did not line up with the motion direction or the digital matrix. This angle represented an average condition. If the phantom were lined up with the motion direction, the special condition arose where there was no motion contribution to any change in resolution. Resolution images were taken with different collimators and from above and below the table.

Image magnification and minification were evaluated from taped data so the information content of each image is identical. The image reductions were 1 to 3, 1 to 5, and 1 to 7 which represented electronic minification on the oscilloscope and not optical minification. The information density evaluation was done using a calculated speed from equivalent static imaging time. The table speed was inversely proportional to the amount of time the detector counted a point source. The higher the speed, the lower the information density. Comparisons were made to determine the efficiency of whole-body imaging with the scanning camera compared with nonmoving separate imaging fields. For the average man, it took seventeen 12-in. circular images to cover the whole body.

RESULTS

Uniformity and linearity. Field uniformity was actually improved in the moving table mode compared with the stationary images. Furthermore, the peripheral edge brightness effect was eliminated. Linearity was also significantly improved with the elimination of peripheral barrel distortion (Fig. 1).

Resolution and field size. There was slight loss of resolution in the moving table mode. In general, the loss was a reduction from a $^3/_{16}$ bar phantom resolution in the moving mode to $^4/_{16}$ resolution in the stationary conventional mode. When different minifications are used, there was slightly greater loss of resolution when the field size of 7 × 2 ft was used. When other field sizes (1 × 1, 3 × 2, and 5 × 2 ft) were used, the change of resolution was minimal, if any (Fig. 2).

Resolution compared with information density. The resolution of the system naturally varies with the information density and deteriorates as information density decreases. For practical purposes, there was negligible advantage to using i.d. above 1,000 cts/cm² (Fig. 3).

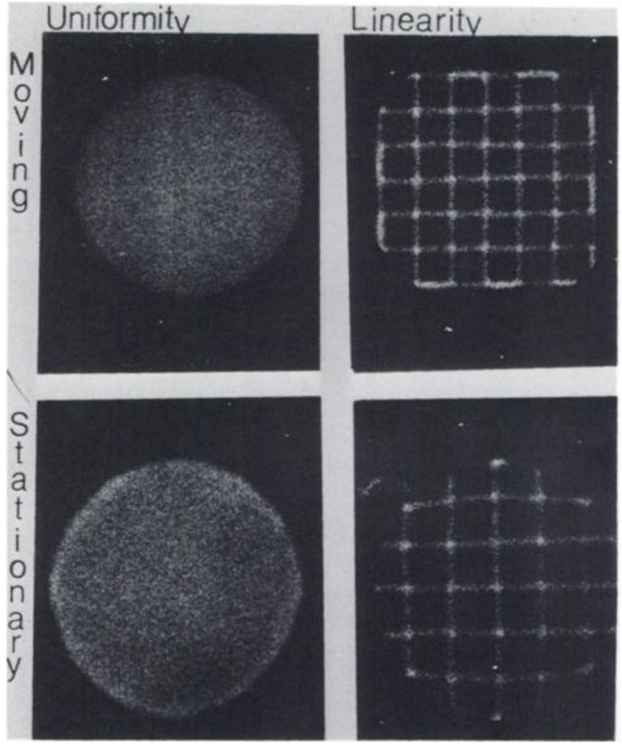

FIG. 1. Field uniformity is at least as good and perhaps even better in moving table mode. Peripheral edge brightness effect has been eliminated with moving table and linearity is improved with elimination of barrel distortion near edge.

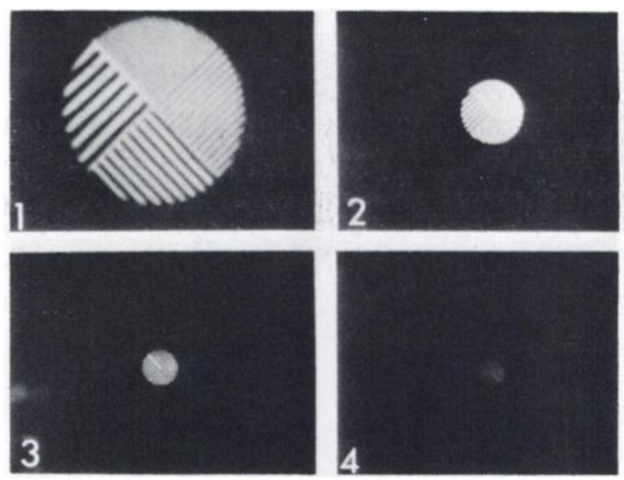

FIG. 2. Resolution compared to field size. For all above information, density is 4,000 cts/cm² and image matrix is 20 pts/cm² on all original images.

Image	Field size	Resolution	
1	1 × 1 ft	3/16 in. barely visible,	¼ in. is well seen
2	3 × 2 ft	3/16 in. visible,	¼ in. is well seen
3	5 × 2 ft	3/16 in. barely visible,	¼ in. is well seen
4	7 × 2 ft	3/16 in. is gone,	¼ in. still visible

Resolution compared with detector position and

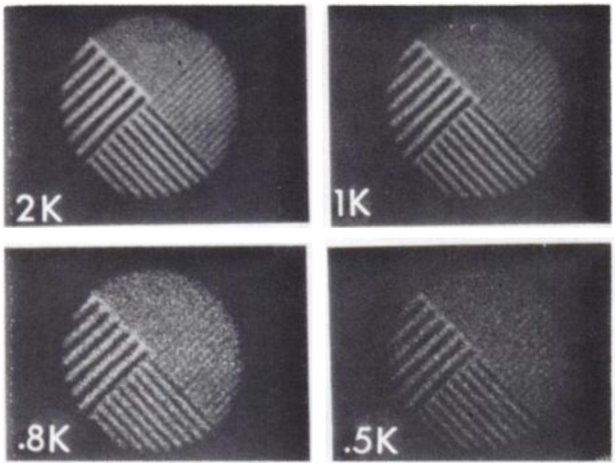

FIG. 3. Resolution and information density.

i.d.	Resolution	
2K/cm²	3/16 in. barely seen,	¼ in. seen
1K	3/16 in. barely seen,	¼ in. seen
0.8K	3/16 in. is gone,	¼ in. is poorly seen
0.5K	3/16 in. is gone,	¼ in. is poorly seen

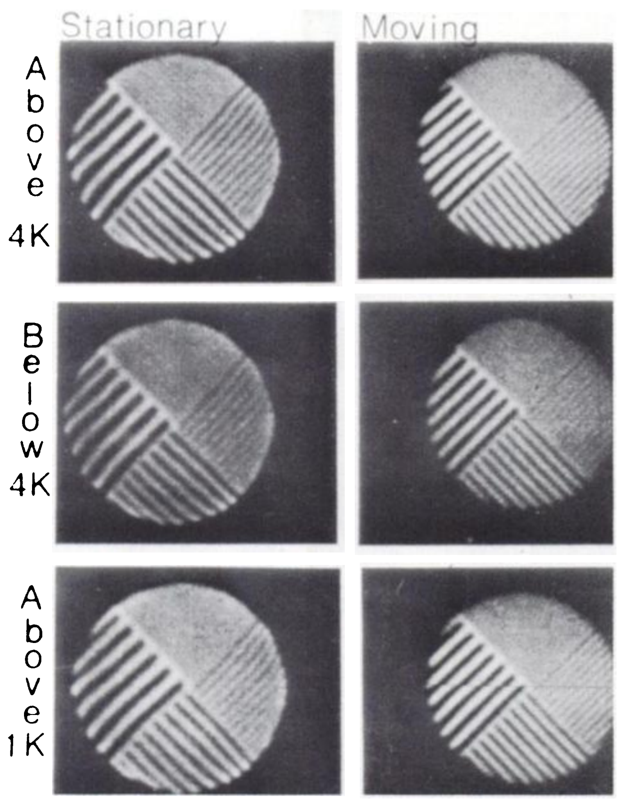

FIG. 4. Resolution. There is loss of resolution when detector is placed below table. 3/16-in. resolution is visible when it is above but lost when detector is placed below due to increased distance between detector and patient and attenuation of tabletop. When high-sensitivity collimator was used, loss of resolution (3/16 in. is gone) occurred with detector above table.

collimator device. There was a noticeable loss of resolution when the detector was placed below the table. In this mode, with the patient lying on a thin mattress, an opening in the table allowed the detector to be brought 1¾ in. from the patient. Attenuation of this space was due to: (A) the mattress, (B) a thin (approximately $\frac{1}{16}$ in.) metal support, and (C) an air gap. These factors contributed to the resolution loss.

When a high-sensitivity collimator was used instead of the high-resolution collimator, there was a noticeable loss in resolution. The imaging time saved by using the high-sensitivity collimator was about 40% (Fig. 4).

Imaging time. Using this imaging system, the time needed to perform an anterior whole-body scintiscan 3 hr after injection of 10 mCi ^{99m}Tc-polyphosphate is about 20 min. Since there is very little to gain from scanning the extremities from both sides, the imaging time can further be shortened by scanning the posterior aspect of the whole body, followed by scanning the anterior aspect of the trunk only. With this approach, an anterior and posterior total-body bone scan can be finished in about 30 min. When whole-body bone scanning is done with the conventional gamma camera alone, usually 15–20 images are required to cover this same area. The total time required to do this varies from about 70 to 90 min. Thus there is a significant saving in time and patient comfort, with negligible loss of resolution. Moreover, all parts of the skeleton are on the same image, permitting relative comparison of corresponding areas.

DISCUSSION

The slight loss of resolution of this whole-body imaging system is surprisingly less than was expected and is offset by the improvement in image linearity and uniformity. This can be explained by the fact that when the stationary mode is in use, the entire detector crystal is used, while in the moving mode, only the central area is used. Since resolution, uniformity, and linearity depend on the tuning and interplay of the photomultiplier tubes, elimination of the less accurate peripheral contributions enhances the image. When the moving table mode is in use, every point in the phantom or patient is "looked at" by the central photomultiplier tubes from different angles at different times. Thus irregularities are averaged and the less accurate peripheral portions of the crystal are excluded.

Unlike the radiographic bone survey, which in most hospitals does not usually include the entire skeleton, multiple images can be taken of the entire body without changing the given radiation dose. Excluding the extremities may be a serious omission since Shirazi (*14*) has shown that about 25% of solitary metastatic lesions are in the extremities.

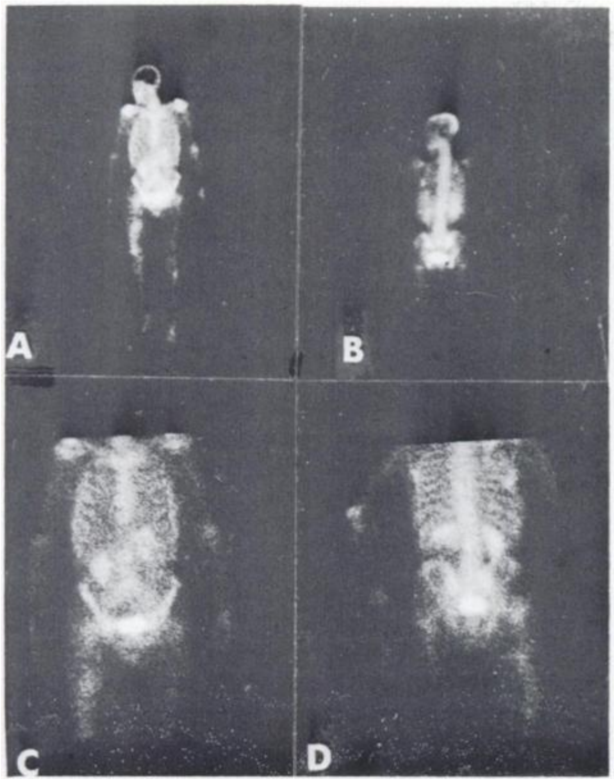

FIG. 5. Scintiphotos A, C, and D were done on patient M 50 with carcinoma of prostate. (A) Whole body (7 × 2 ft) scintiphoto done with detector above supine patient on table. (B) Anterior view (detector above patient and table) on 40-year-old female with breast cancer. Multiple areas of increased activity seen over skull and ribs. (C) Done from tape replay with "area of view" setting of 5 × 2 ft. Same lesion seen in more detail. (D) Done from tape replay when detector was placed below table and patient. Area of view was 5 × 2 ft. Same lesion was seen but not as well. Please notice posterior bony structures (spine and posterior ribs) were better demonstrated.

Therefore it would seem extremely important to include the extremities in all metastatic bone surveys, particularly if the central areas are negative (Fig. 5).

The size of the moving table is a certain disadvantage in a small department. The table is far less versatile than a conventional imaging table and might not normally be used for other routine studies.

CONCLUSION

Since the bone scan is more sensitive and the radiation dose using Tc-PP is now lower than a routine radiographic skeletal survey, we conclude that for the patient with a known or suspected malignancy, a whole-body bone scan should be done as part of the initial workup. If the bone scan is positive or suspicious, these areas could then be further studied radiographically to improve the specificity of the findings. In certain neoplasms which produce mainly an osteolytic response (such as multiple myeloma and renal cell carcinoma), one might still obtain a radiographic skeletal survey in the face of a negative whole-body survey in view of the reduced specificity of the Tc-PP scan in these conditions. Use of this hybrid scanning camera is a most effective method of performing a whole-body scan.

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