Measurement of 24-Hour Whole-Body Retention of Tc-99m HEDP by a Gamma Camera

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Measurement of 24-hr whole-body retention of Tc-99m HEDP, using a shadow-shield, whole-body monitor, has been shown to be a sensitive measure of skeletal metabolism and of value in the diagnosis of metabolic bone disease. A new method of measuring the retention using a gamma camera, with a scanning (fishtail) collimator and patient placed at 2.3 m distance, has been evaluated in 18 patients undergoing routine bone scans. The patients also had whole-body retention measured using the whole-body monitor (WBM), and the two methods correlated well, yielding a regression line GC% = −0.82 +0.98 WBM%, r =0.975, p < 0.001. The limitations to, and repeatability of, the gamma-camera measurements are discussed. This work shows that measurements of whole-body retention can be obtained in any nuclear medicine department possessing a gamma camera with a suitable collimator.

J Nucl Med 22: 542–545, 1981

Bone scanning with the technetium-labeled diphosphonates has proved somewhat disappointing in the assessment of patients with metabolic bone disease, since scan appearances are often apparently normal when the skeleton is diffusely involved (*1–5*). In such cases an awareness of abnormality depends upon a subjective impression of increased tracer uptake throughout the skeleton. Accurate quantitation of tracer uptake by bone is required for a positive identification of increased skeletal metabolic activity. Measurement of 24-hr whole-body retention (WBR) of Tc-99m diphosphonate (Tc-HEDP) is a new technique by which total skeletal uptake of tracer is obtained. We have shown that patients with primary hyperparathyroidism, osteomalacia, renal osteodystrophy, and Paget's disease can be clearly differentiated from a control population by this technique (*5–7*).

Whole-body retention of diphosphonate provides a simple and sensitive measure of skeletal metabolism, and potentially has widespread application in clinical practice (*5–9*). However, since whole-body monitors (WBM) are not widely available, the means to perform such studies appear to be limited to only a few centres (*1*). This is not the case, and this communication describes how accurate measurement of 24-hr WBR of Tc-HEDP may be made using a gamma camera with a suitable collimator, which makes the technique available in most nuclear medicine departments.

MATERIALS AND METHODS

Eighteen patients with suspected abnormalities of skeletal metabolism were given 15 mCi of Tc-HEDP* by intravenous injection as part of a standard bone scan. Diagnoses were: Paget's disease, six; osteoporosis, four; primary hyperparathyroidism, three; renal osteodystrophy, one; thyrotoxic, one; unestablished, three. The whole-body count was measured 5–15 min after injection by positioning the patient 2.3 m from a wide-field gamma camera fitted with the "fishtail" collimator normally used for whole-body imaging with a scanning

Received Aug. 20, 1980; revision accepted Oct. 31, 1980.

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gamma camera. This collimator is parallel in one dimension and diverging in the other. When the collimator face is vertical, this gives a field of view of 0.35 m (FWHM) horizontally and 2.5 m vertically at a distance of 2.3 m, where patients could be accurately positioned standing against the wall of the room. This enabled a rather distorted image of the whole patient to be obtained by the gamma camera. Anterior, posterior, and lateral views of 30 sec each were acquired, typically yielding 120 K counts per view anteriorly and posteriorly, with 100 K counts per view laterally, using the Tc-99m photopeak with a 20% window. The anterior and posterior views were then repeated. These measurements were carefully repeated at 24 hr, with 100-sec timing, giving approximately 5 K counts (not including background) for patients with a normal whole-body retention of 20%. Using appropriate background, which was measured on both days, and decay corrections, the 24-hr WBR of Tc-HEDP was calculated. Within 18 days of the bone scan, each subject also had a 24-hr WBR of Tc-HEDP measured in the standard way using the whole-body monitor and an activity of 50 μCi (*5*). On the whole-body monitor, patients lie on a table and pass between detectors above and below them. Thus the mean of the anterior and posterior views, as measured with the gamma camera, is best for comparison with the whole-body monitor's results.

RESULTS

Figure 1A plots the 24-hr WBR for 18 patients, as measured by gamma camera (mean of the two anterior and two posterior views), against the results obtained on the WBM. The individual values for the various diagnoses as measured on the whole-body monitor were consistent with those reported previously (*5*). The mean

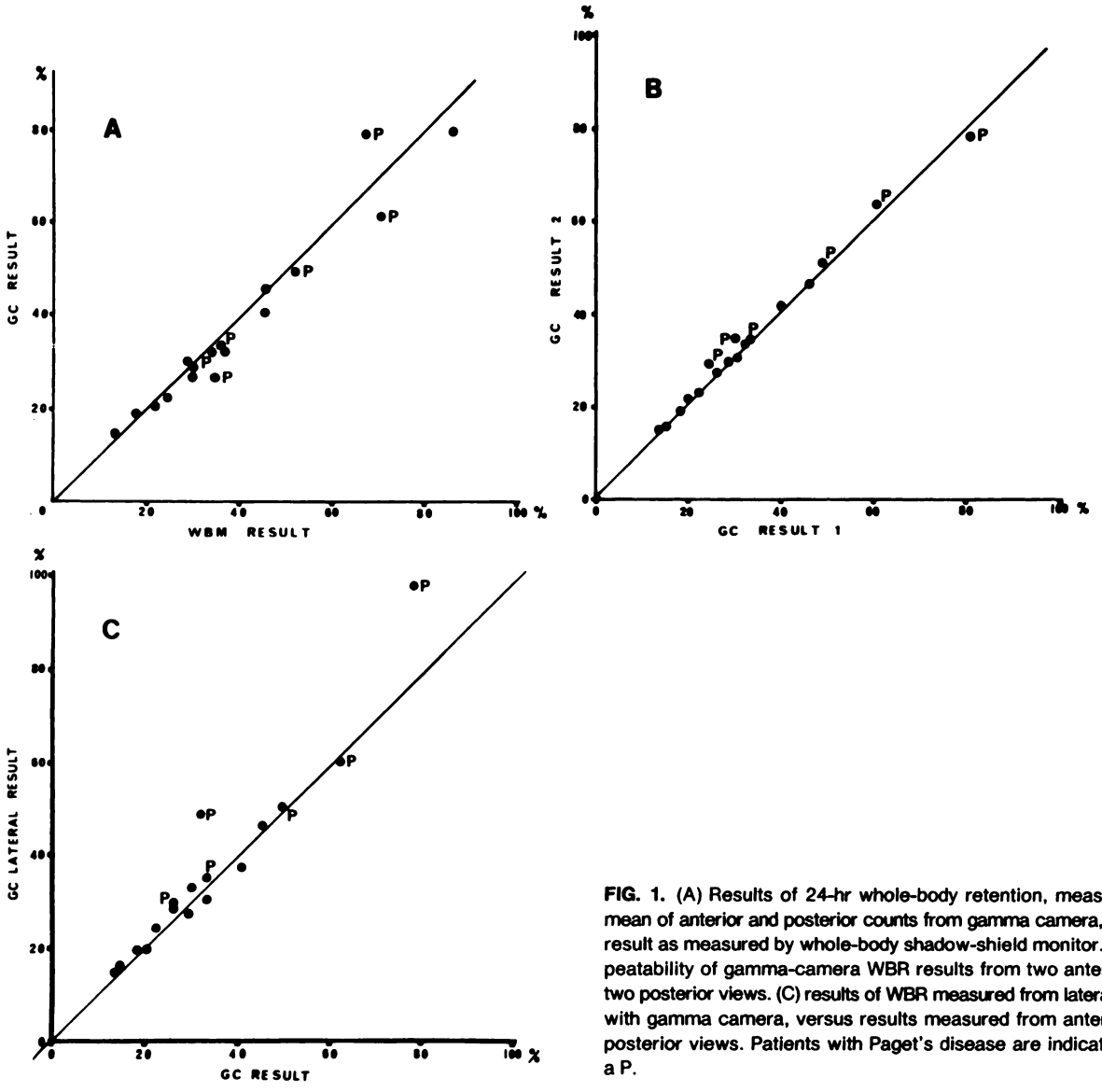

FIG. 1. (A) Results of 24-hr whole-body retention, measured as mean of anterior and posterior counts from gamma camera, against result as measured by whole-body shadow-shield monitor. (B) Repeatability of gamma-camera WBR results from two anterior and two posterior views. (C) results of WBR measured from lateral views with gamma camera, versus results measured from anterior and posterior views. Patients with Paget's disease are indicated with a P.

TABLE 1. APPROXIMATE PARAMETERS FOR GE MAXICAMERA II (WIDE FIELD) AND OHIO NUCLEAR STANDARD-FIELD GAMMA CAMERA, AS USED TO MEASURE WHOLE-BODY RETENTION*

Camera	Collimator	Area of crystal (cm^2)	Field of view at 2 m† (cm)	Background (count/sec)	Sensitivity to point source (2 m) (cps/μCi)	Sensitivity to patient (2 m) (cps/μCi)
Wide-field	scanning	1090	240 X 34	30	0.663	0.270
Wide-field	none	1590		525	52	21
Standard	diverging	546	circle, 185 cm diam.	12	0.192	0.078
Standard	none	918		290	37	15

A 20% window was centered on Tc-99m photopeak.

† Initial sensitivity measurements were made at 2 m and patient studies at 2.3 m for convenience. Results at the two distances were not significantly different.

percentage difference between the results is 7.6% and a least-squares linear regression gives GC% = −0.82 + 0.98 WBM%, r = 0.975, $p < 0.001$. The two methods for measuring WBR agree well and show that a gamma camera can be used to measure WBR satisfactorily in patients undergoing routine bone scans. The results obtained on the whole-body monitor tend to be higher than those with the gamma camera, probably due to the different detector geometries, but the variations in the results are not significant. Figure 1B shows the variation of 24-hr WBR measured when the patient is repositioned in the posterior and anterior views. Repeatability is good, the mean percent difference between the results being 3.3%. Figure 1C indicates the results obtained for 24-hr WBR as measured by the lateral against the anterior and posterior views. The results again agree well, but as can be seen in all three graphs, the patients with Paget's disease tend to show the greatest differences. This is due to the focal uptake of Tc-HEDP in these patients, which leads to significant redistribution between the Day 1 and Day 2 measurements. In the case of the patient with nearly 100% WBR measured laterally in Fig. 1C, the side of one fibula took up an unusually high proportion of the dose causing the variation between the results (see Discussion).

DISCUSSION

There are several factors to be considered when using a gamma camera for 24-hr WBR: (a) the count rate response of the gamma camera; (b) background count rate; (c) sensitivity and uniformity of the collimator; and (d) redistribution of radiopharmaceutical in the patient.

Normal patients retain approximately 20% of the injected HEDP at 24 hr; thus approximately 1/80th of the injected activity remains at that time. This, along with the sensitivity of the gamma camera and the background count rate (Table 1), provides the limitations to the injected dose from statistical considerations (Appendix). Since the gamma camera is approximately 80 times more sensitive without a collimator (Table 1), this might be thought to present a better method of measuring WBR, even though the background is increased by a factor of 17.5. However, for patients undergoing routine bone scans, the initial measurement after the injection of 15 mCi of Tc-HEDP results in the camera's being operated in its nonlinear count rate response region on Day 1. Simple count-rate corrections, such as can be determined by a standard phantom with water scattering, are inapplicable due to the well-known problems of scattering within the patient, pulse pileup, source geometry variations, and scattered radiation from around the room, all affecting the pulse-height distribution at high count rates (*10–12*). These effects vary considerably from patient to patient, and could be corrected for only by using phantoms with properties identical to those of each individual patient.

Use of the fishtail collimator enables the initial count rate on Day 1 to be within the linear count-rate response of the camera, as well as reducing the background. The pulse-height distribution from the patients is also similar on both days due to the elimination of much of the scattered radiation. The varying sensitivity of the collimator in the diverging (vertical) direction is relatively unimportant, since only redistribution of radiopharmaceutical affects results, and the initial vascular distribution on Day 1 has similar geometry to the Day 2 bone distribution. This problem is most obvious in cases with focal abnormalities such as Paget's disease (as mentioned earlier), where considerable changes in distribution of radiopharmaceutical occur. In such cases, however, the 24-hr WBR is markedly increased (*5*), yielding clear distinction from the normal group of patients (Fig. 1). The large patient-to-camera distance (2.3 m) reduces the effects of changes in source-to-detector distance, besides which patients can be accurately repositioned.

If a bone scan is not required, but only a measure of skeletal metabolism, 24-hr WBR could be measured by a gamma camera using a considerably lower activity than 15 mCi. If one needs to measure a normal 24-hr

WBR to a precision of 5% [i.e., result = (20 ± 1)%] within a total time on Day 2 of 1000 sec for patient and background measurements, then statistical considerations (Appendix) show that an activity of 2 mCi could be used. Here again use of the gamma camera without a collimator is not practical, since the much higher background, with significant fluctuations within a nuclear medicine department, requires a Day 1 activity that would cause nonlinear operation of the camera. Evaluation of WBR at a shorter time interval (e.g., 6 or 8 hr) might be a suitable addition to this test (*5*), since even at this time WBR is a measure reflecting skeletal uptake, although incomplete and variable excretion of nonskeletal Tc-HEDP would affect the result. Moreover, if there were any uncertainty, the result could be confirmed by a measurement at 24 hr. Note again that considerably lower activities could be used if a 6, 8, or even a 12-hr result were used as standard.

Although the fishtail collimator has desirable properties, WBR could also be measured using a gamma camera with any collimator capable of including the whole body in its field of view at a reasonable distance. For example, a 25-cm camera detector with a conventional diverging collimator can be used (Table 1), taking account of the factors already discussed.

CONCLUSION

We have shown that measurement of 24-hr WBR can be made using a gamma camera and could be used either independently or in addition to standard bone scans. This test provides a sensitive measure of skeletal metabolism (*5–7*) and is simple, noninvasive, has good reproducibility, and can be performed in any nuclear medicine department possessing a gamma camera with suitable collimator.

FOOTNOTE

Osteoscan, Procter and Gamble, Cincinnati, OH.

ACKNOWLEDGMENTS

We thank Mrs. E Scott of the Dept. of Nuclear Medicine for her measurements of whole-body retention on the Whole-Body Monitor.

APPENDIX

Statistical accuracy of the measurement of 24-hr WBR by a gamma camera. The random error in a normal WBR of 20% will be estimated as a worst case. On injection of 15 mCi Tc-HEDP and the patient positioned at 2.3 m from the camera, typical anterior and posterior count rates are 4000 cps for the IGE camera with fishtail collimator, these being well within the linear range. The background count rate (B) is typically 30 cps. At 24-hr, with a normal patient, the net anterior and posterior count rates are $1/5 \times 1/16 \times 4000 = 50$ cps (C), to which background (which must be counted correctly on both days) will be added ($S = C + B$). Only the second-day measurement has significant random error.

The standard deviation (σ) in the measurement of C, the net cps from the patient ($C = S - B$) is

$$\sigma = \sqrt{\frac{S}{t_S} + \frac{B}{t_B}}$$

which for $t_S = t_B = 100$ sec, as was used in this investigation, yields

$$\sigma = \sqrt{\frac{80}{100} + \frac{30}{100}} = 1.05 \text{ cps.}$$

Thus the fractional error in C is: $1.05/50 = 2\%$, and the probable range of 24-hr WBR is $(20 \pm 0.4)\%$ for a normal patient. It must be emphasized again that there are other, systematic, sources of error, such as those involved in repositioning both patient and camera, photopeak variation, etc., but steps can be taken to minimize these.

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