A DOUBLE-ISOTOPE APPROACH TO THE ESTIMATION OF DEPTH OF SOURCE IN SCINTIGRAPHIC MATRICES

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The depth of an organ such as the kidney or thyroid can be estimated by a double-isotope method (*1*). The basis of the method is the calculation of counting-rate ratios of strong and weak gamma rays from different isotopes of the same element. Therefore with double-isotope digital scanning it may be possible to perform quasi three-dimensional scanning by determining the depth of the radioactivity over the entire scan and thus locate spatially areas of diminished function.

Using a two-channel scanner with a digital computer-processed readout, we have made preliminary experiments in this regard.

MATERIALS AND METHODS

A circular phantom, 13.8 cm i.d. and 3 cm thick, was made to contain nine solid methyl methacrylate cylinders which simulate space-occupying lesions in an organ (Fig. 1). Two of the solid cylinders were 3 cm in diameter and 1 cm thick, two were 2 cm in diameter and 1 cm thick, two were 1 cm in diameter and 2 cm thick, two were 0.5 cm in diameter and 1 cm thick and one was 1 cm in diameter and 3 cm thick. The last cylinder extended from the top to the bottom inner surface of the phantom. The paired cylinders were distributed equally around the periphery of the phantom, one of each pair being cemented to the top and one to the bottom surface. The thickness of the counting surface was 0.2 cm.

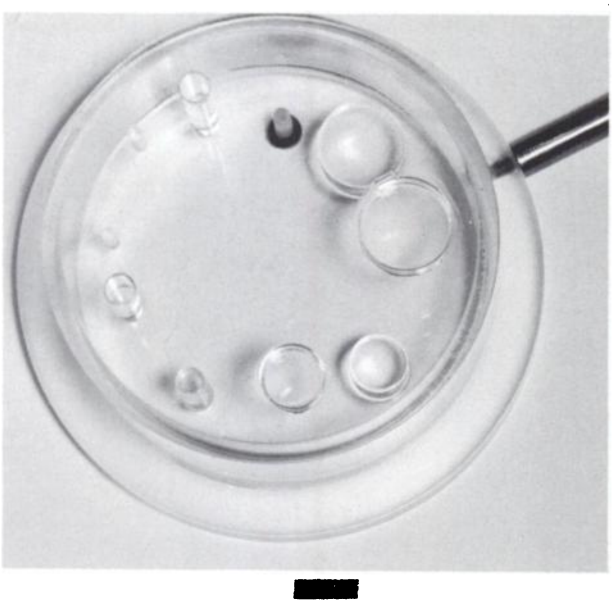

FIG. 1. Circular phantom, 13.8 cm in diameter, with "filling defects" of various diameters on upper and lower surfaces; one is through-and-through (see text for dimensions).

This phantom was filled with a solution containing 100 μCi of ^{125}I and 50 μCi of ^{131}I as iodide and some dye to allow detection of leakage. It was scanned at a depth of 4 cm (measured from the surface of the probe to the top of the phantom) in a galvanized iron tank, 61 cm long $\times$ 38.5 cm wide $\times$ 25.5 cm deep, containing 50 liters of water.

Scanning was performed with a modified, commercially available instrument equipped with a 3-in. NaI(Tl) crystal and 19-hole focusing collimator (Picker Magnascanner). Signals from the dual pulse-height-analysis systems were recorded on two channels of an eight-channel digitizing magnetic-tape recorder in computer-compatible format for processing by an IBM 7040 computer (*2*). Resolution capabilities of the system have been given previously (*3*).

The discriminator settings of the pulse-height analyzers were optimal for counting the individual isotopes (determined by spectral analysis in water): the 0.364-MeV peak of ^{131}I and the 0.035-MeV peak of ^{125}I were straddled by the upper and lower discriminators of the two channels, respectively. This system collects scan data along with x-y information and processes each datum point according to the resolution capabilities of the data-gathering mechanism (*3,4*). The point of maximum intensity on the matrix is found and divided into 20 counting-rate increments, each 5% of maximum

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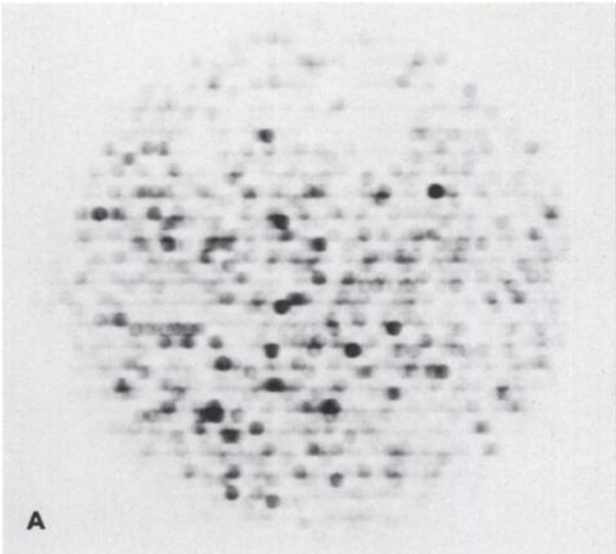

FIG. 2. A is photoscan of ^{131}I in phantom. B is three-level computerized plot of scan data gathered simultaneously with photoscan. Asterisks depict counting-rate increment that is 5% of maximum counting rate. Counting rates below this are represented by blanks and those above by hyphens. Two largest filling defects shown in Fig. 1 (right upper portion of photograph) are depicted at top of this scan.

intensity. After processing (*5*), three scan matrices in correct spatial relationship are printed out, one from the ^{131}I channel, one from the ^{125}I channel and one as a ratio of ^{125}I-to-^{131}I counting rates.

Various type symbols were assigned to the 20 counting-rate increments in increasing order as described previously (*2*). Alternatively, an individual increment could be assigned a character such as an asterisk with all increments below it represented by blanks and all increments above it by hyphens. These are referred to as three-level plots.

In addition to these computer-processed digitized scans, a conventional photoscan of the ^{131}I data was made.

RESULTS

The conventional photoscan (Fig. 2A) of the ^{131}I counts arising from the phantom is mottled and shows little detail. It was scanned at 35.7 cm/min. In a computer-processed three-level plot in which a single level of ^{131}I activity (5% of maximum) is depicted by asterisks (Fig. 2B) all except the smallest two cylinders are detectable, but none of the voids can be localized as proximal or distal.

Figure 3 is a diagram of the cross-section of the phantom through the centers of the largest cylinders and of the relative counting rates of ^{131}I and ^{125}I made through this level. The 0.364-MeV ^{131}I gamma rays are less inhibited by the thick upper cylinder than are the 0.035-MeV ^{125}I gamma rays and therefore the upper cylinder is better depicted on ^{125}I display. Depiction of the lower cylinder is better in the ^{131}I channel because the bottom layer of liquid is counted more efficiently in the ^{131}I channel than in the ^{125}I channel due to the relative inhibition of the 0.035-MeV gamma rays by the fluid above it. On the basis of the ^{125}I-to-^{131}I ratio, the proximal (upper) cylinder appears as a "hole" and the lower cylinder is associated with a higher ratio or apparent "hot spot."

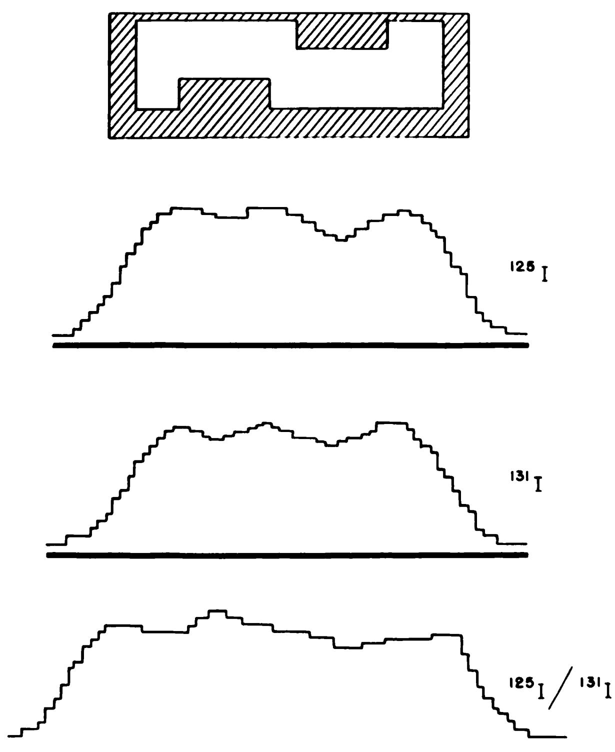

FIG. 3. Cross-section through centers of largest cylinders and relative counting rates recorded by scanner probe.

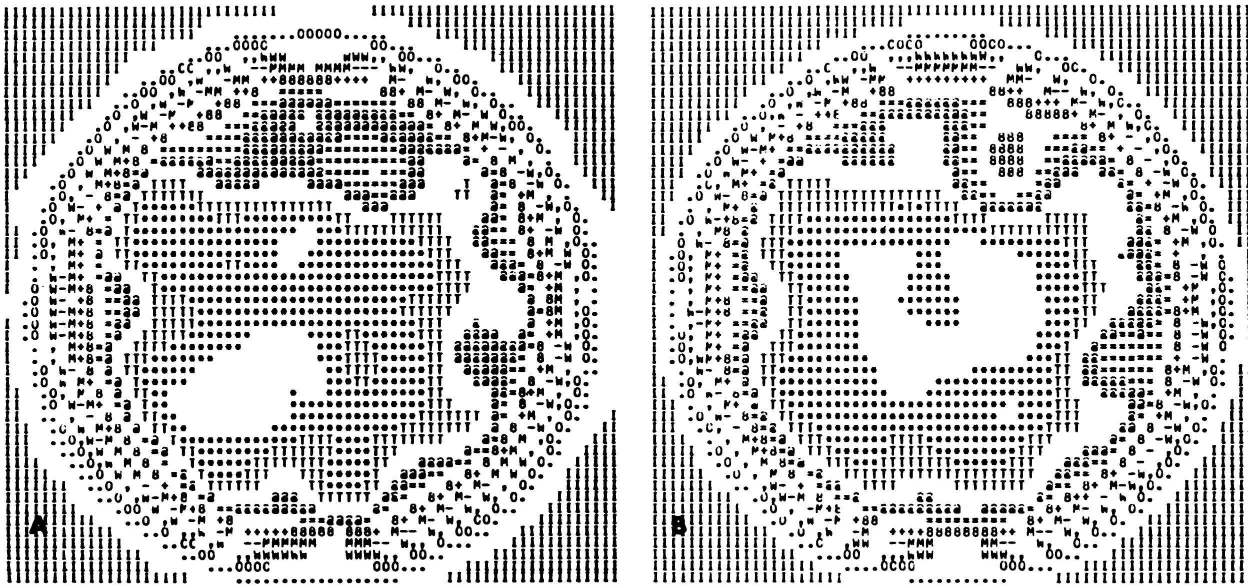

FIG. 4. Digitized scans made from same data shown in Fig. 2. Counting rates are represented, in increasing order, by: I, blank, ·, 0, blank, ·, W, blank, —, M, blank, +, 8, blank, =, @, blank, T, *, blank. A contains ^{131}I data; all except two smallest cylinders can be seen. B contains ^{125}I data; same cylinders can be seen but with more difficulty than on ^{131}I scan. Orientation of phantom is same as shown in Fig. 2.

The 20-level digitized scan (Fig. 4A) made from the ^{131}I data reveals aberrations in the isocount contours in all except the two smallest cylinders—proximal, distal and through-and-through. The 20-level scan from the ^{125}I data (Fig. 4B) reveals the same, except the distal cylinders are less well delineated. A 20-level digitized plot of the ^{125}I-to-^{131}I ratios (Fig. 5) reveals the three largest upper (proximal) cylinders to be "cold" and the three distal ones to be "hot." The two smallest cylinders were not depicted. The through-and-through cylinder appeared "hot." The ratio over the wall of the phantom is also high although it contained no radioactivity.

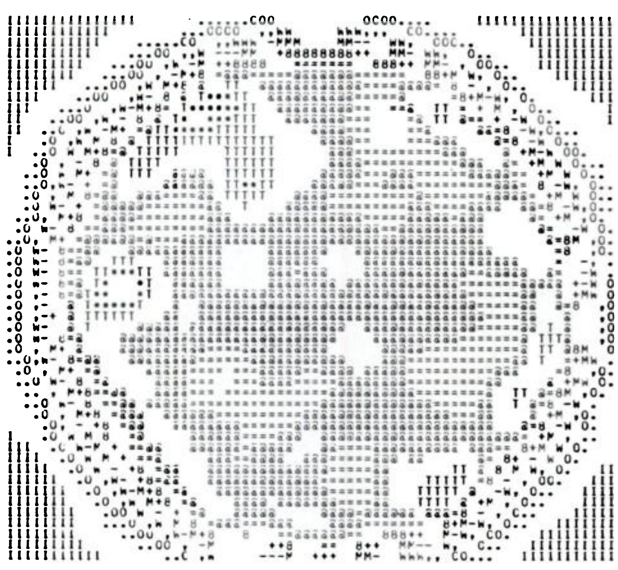

FIG. 5. Digitized plot of ^{125}I-to-^{131}I ratios. High ratios are seen over distal "filling defects" while low ones are seen over proximal defects; high ratios are also seen over through-and-through cylinder. Orientation of matrix to phantom is that shown in Fig. 2.

DISCUSSION

These examples indicate two general advantages of computer-processed scans: increased resolution of the scans and the capability of manipulating the matrices mathematically. The photoscan shows only suggestions of the two largest cylinders in the phantom, and the three-level plot shows all but the two smallest of them. The fact that the "hot spots" on the double-isotope scan are produced by the distal filling defects may lead to added enhancement of diagnostic acumen for these lesions which are more difficult to diagnose.

The fact that the derivation of scintiscan matrices by computer processing of ratios of counting rates from two isotopes measured simultaneously permits localization of the depth of filling defects within an organ is indicated by these preliminary experiments. In the example presented, only the ratios are depicted; the actual depth of each level must be calculated from data obtained from an *in vitro* model. Previous work (*1*) based on point-source and probe-counting techniques indicates that this can be effected to within a few millimeters.

The fact that higher ^{125}I-to-^{131}I ratios are associated with the edge of the walls of the methyl methacrylate phantom and the through-and-through cylinder probably resulted from greater shielding of the 0.035-MeV gamma rays of ^{125}I by the methyl methacrylate than of the 0.364-MeV gamma rays of ^{131}I. This would not be expected to pose a clinical problem.

More work is needed to improve the format of the readout of digital scans. Additional work in the ratio derivation may also improve the final data-presentation format and enable more precise localization of the source of radioactivity for calibration. Data presented from these phantoms are preliminary. Work in progress in our laboratory suggests that the method may be useful clinically for scanning the thyroid and kidneys.

SUMMARY

An approach to three-dimensional scanning by a double-isotope technique is presented in which computer-processing of data is used.

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