DIGITAL-COMPUTER INTERPRETATION OF RADIOISOTOPE DISTRIBUTION PATTERNS

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The digital computer may become a valuable aid in improving the interpretation of radioisotope distribution patterns (scans). A number of investigators have used the computer to enhance certain features of the radioisotope distribution pattern (*1–11*). These enhanced images are then interpreted by the physician. A computer program has been developed that accepts a digitized radioisotope distribution pattern and, rather than producing a modified or enhanced image, provides a direct interpretation. The initial program that is described in detail elsewhere (*12*) has been developed for distribution patterns of the thyroid gland and has been designed to classify the images as either normal or abnormal.

METHOD

When a radioisotope distribution pattern is digitized for computer classification, it is then an array of several hundred numbers. Theoretically the pattern could be subjected to analysis while in that form. From the practical standpoint it is desirable to have the pattern represented by only a small set of numbers. These numbers, however, must reflect all of the possible organ abnormalities (distortion, nodules, etc.) if the interpretation system is to be sufficiently sensitive. The significant aspect of the work described here is the reduction of a digitized pattern of the thyroid gland to 18 numerical parameters which can be used for computer classification of the pattern.

The distribution of radioactivity along various axes passing through the thyroid gland creates "profiles" of the gland which can reflect abnormalities in size and shape of the organ. The profiles are computed directly from the digitized scan data by summing the total number of counts recorded at each point along a selected axis. It has been found that six profiles are sufficient to describe the gland for the method of analysis to be used here. These are the profiles of:

1. the total gland in the sagittal plane
2. the total gland in the horizontal plane
3. the right lobe in the sagittal plane
4. the right lobe in the horizontal plane
5. the left lobe in the sagittal plane
6. the left lobe in the horizontal plane.

The general size and shape of each profile is quantitated in the following manner. The second, third and fourth moments (m_2, m_3 and m_4) about axes passing through the "center of activity" of each profile are given, respectively, by

$$m_2 = m_2(0) - m_1(0)^2$$
$$m_3 = m_3(0) - 3m_1(0)m_2(0) + 2m_1(0)^3$$
$$m_4 = m_4(0) - 4m_1(0)m_3(0) + 6m_1(0)^2m_2(0) - 3m_1(0)^4$$

where $m_r(0)$ is the rth moment about the origin of the profile coordinate system.

The second moment (m_2) about the center of activity can be shown to be the average of the squares of the spread of the activity about the center of the profile and can therefore be used to quantitate the general dispersion or size of each profile.

The extent of departure from symmetry, or skewness, of each profile is given by

$$Sk = \frac{\sqrt{\beta_1(\beta_2 + 3)}}{2(5\beta_2 - 6\beta_1 - 9)}$$

where

$$\beta_1 = m_3^2/m_2^3$$

and

$$\beta_2 = m_4/m_2^2.$$

A third characteristic, the kurtosis, expresses the tendency of the profile to either concentrate around

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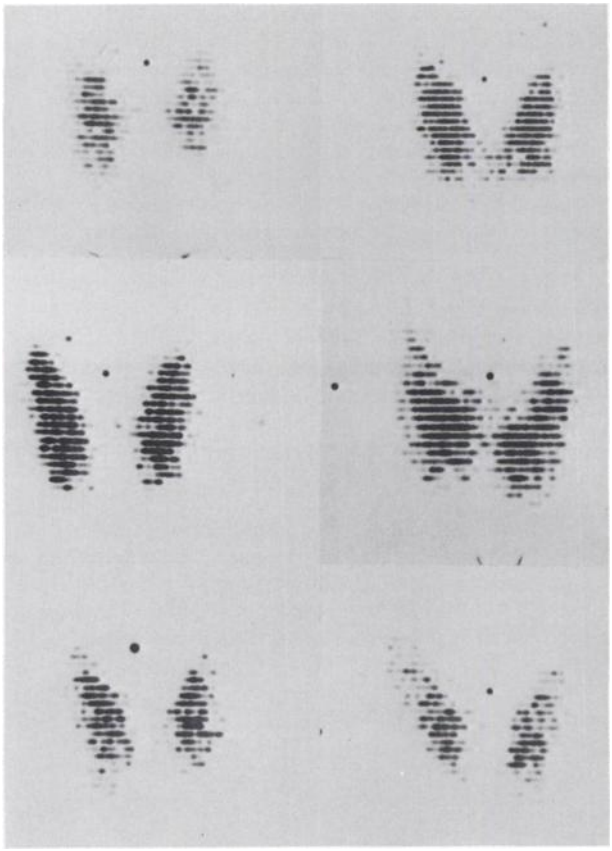

FIG. 1. Six radioisotope distribution patterns showing range that was classified as normal by both physician and computer.

the center or spread out toward the edges. The kurtosis can be expressed in terms of moments by

$$Ku = \frac{m_4}{m_2^2} - 3.$$

The three characteristics—dispersion, skewness and kurtosis—of each of the six profiles give 18 numerical parameters which are sensitive to pathological conditions which are reflected in the radioisotope distribution pattern.

A group of normal patterns has been used to establish a range for the 18 characteristics used to describe these images.

The computer evaluates a particular distribution pattern by determining if all of the 18 describing characteristics are within the normal range.

RESULTS

Sixty radioisotope distribution patterns of the thyroid gland have been analyzed by this computer program. Twenty-one of these patterns were classified as normal by the physician. Of these 21 patterns, the computer classified 20 as normal and one as abnormal. The range of these normals is illustrated by the six patterns in Fig. 1 which are taken from this group. The remaining 39 were found by the physician to indicate several pathological conditions and to be abnormal. The computer classified 37 of these as abnormal and two as normal. Six typical patterns selected from this group are shown in Fig. 2. A review of the two cases which the computer erroneously classified as normal revealed that the physician's report had indicated only a "possible" abnormality. In summary, the computer's interpretation as to normal or not normal agreed with the physician in 57 out of the 60 cases studied.

DISCUSSION

While it is not anticipated that the digital computer will replace the physician in the interpretation of radioisotope distribution patterns, it is significant that a pattern can be quantitated and classified by modern data-processing equipment. The quantitative method of the computer should supplement the essentially subjective approach of the physician to image interpretation.

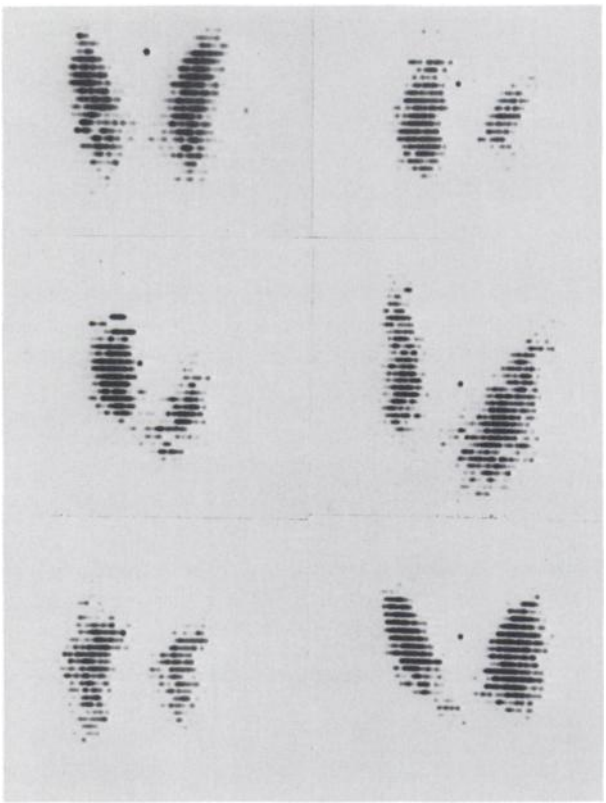

FIG. 2. Six radioisotope distribution patterns that were classified as abnormal by computer and physician.

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