An Image Processing Method for Feature Extraction of Space-Occupying Lesions

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Space-occupying lesions (SOL) and irregular intensity distribution are usually observed in the radioisotope images of human liver diseases, hepatic cancer, etc. This paper describes a new image processing method for evaluating such SOL by using a computer. This method analyzes quantitatively the convex and the concave structure of the contour line. From the processed results, the contour lines of radioisotope images of liver diseases are more ragged than those of normal ones; the region of SOL is extracted by the abnormal raggedness in the contour structure.

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In recent years, image processing and pattern classification procedures for medical images have been very actively investigated by using computers and other instruments. The purposes of these investigations are automatic diagnosis, quantitative image analysis, etc. The radioisotope image of an abnormal human liver contains defects, irregular contour structure, and irregular intensity distribution. The detection of such features is extremely important in medical diagnosis. A number of methods for feature extraction of the radioisotope image have been proposed (*1–5*). This paper describes a quantitative analysis method for evaluating such SOL by the abnormality in the structure of the contour line of radioisotope image. This method has the advantage that the convex and concave structure of the contour line is denoted quantitatively by a new evaluation factor, distance D_l.

IMAGE PROCESSING

The radioisotope image of abnormal human liver has some characteristics compared with the normal liver, mentioned above. Figure 1A and B show typical examples of normal and abnormal radioisotope image, respectively. These images are obtained about 20 to 30 min after i.v. injection of 4 mCi technetium-99m tin colloid and using a gamma camera.* The abnormal case (B) has many SOL in its contour. Generally, the radioisotope image includes much quantum noise. The accurate detection of defects and the classification of radioisotope images into normal or abnormal is affected by the quantum noise and the blur in the image. Therefore, several useful preprocessing techniques are desired. The method discussed in this paper extracts features of the contour structure of radioisotope image in consideration of the elimination of the noise and the blur in the image.

DETECTION OF CONTOUR LINE

The following preprocessing techniques for the extraction of a contour line from a radioisotope image puts the two-threshold method such as the visual threshold method (*6*) and the iterative local averaging method for smoothing, the first method described by Lev et al. (*7*), to practical use. Acquired image data, 512 by 512 pixels, in the computer is first normalized to 256 gray levels, as the minimum intensity in each image has different value. After this processing, a contour part is extracted by using the two-threshold method. This method sets two threshold levels, V_1 and V_2, to the gray level of image data. The level V_2 is the lowest value within the nonaffected region of the background noise, and V_1 is set 25 gray levels higher than V_2. Then, the image data between two thresholds is collected and transferred to 255 levels, and image data in other regions is transferred to 0. This binally collected image data provides a contour part of a corresponding radioisotope image. The extracted contour part is actually composed of many closely situated dots. For the detection of a contour line in this contour part with high accuracy, the extracted contour part is smoothed by using the iterative local averaging method. Figure 1C and D show processing results by the two-threshold method

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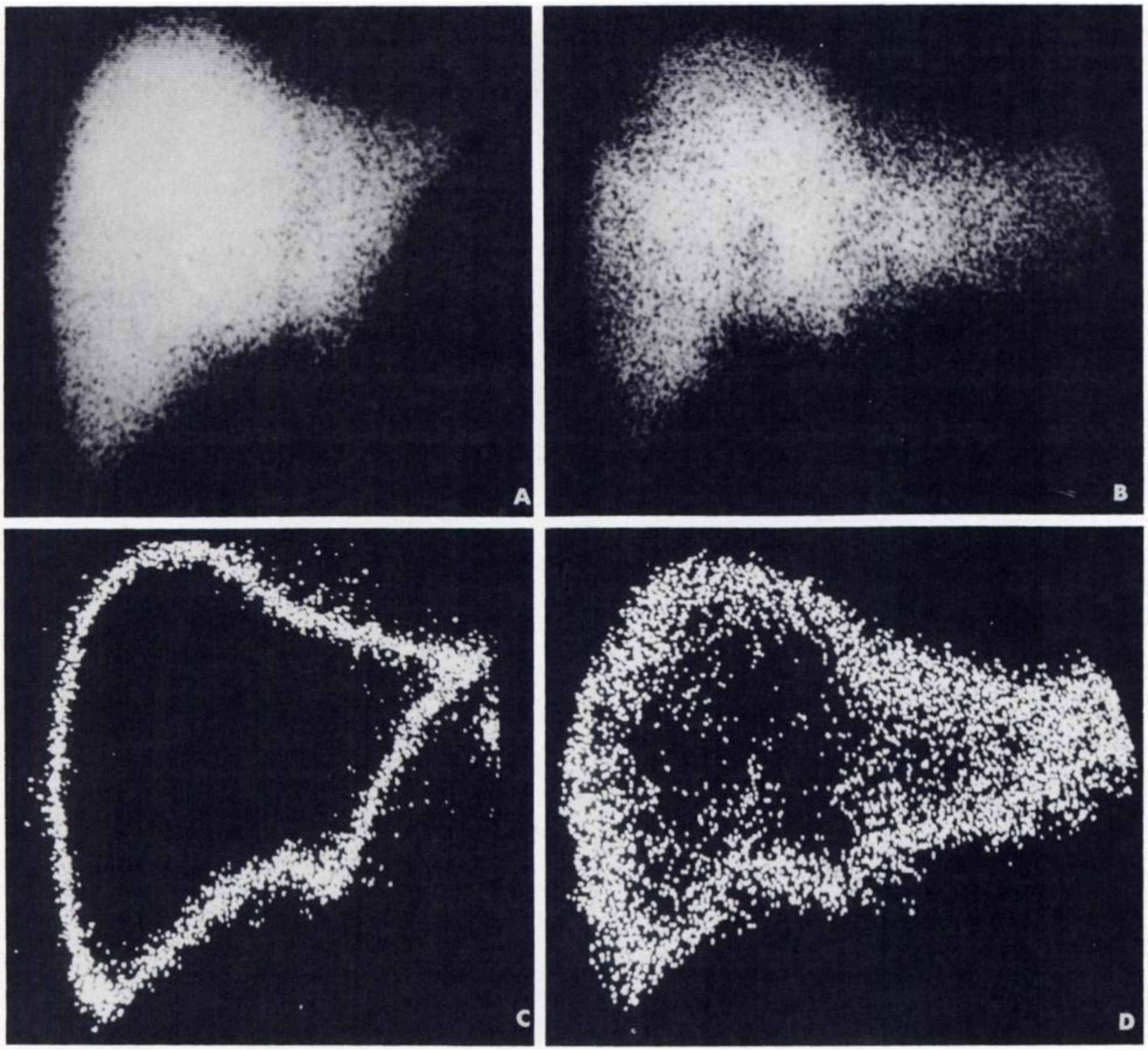


FIGURE 1
Radioisotope images of normal (A) and abnormal liver (B) and their contour parts (C),(D). Abnormal case (B) has some low density area and irregular contour structure. Contour part (C) and (D) are extracted by two-threshold method

of Fig. 1A and B. The levels V_1 and V_2 for these two cases are 75 and 50, 115 and 90, respectively.

CONTOUR STRUCTURE ANALYSIS

The method for extracting the convex and concave structure consists of the following five major processing steps.

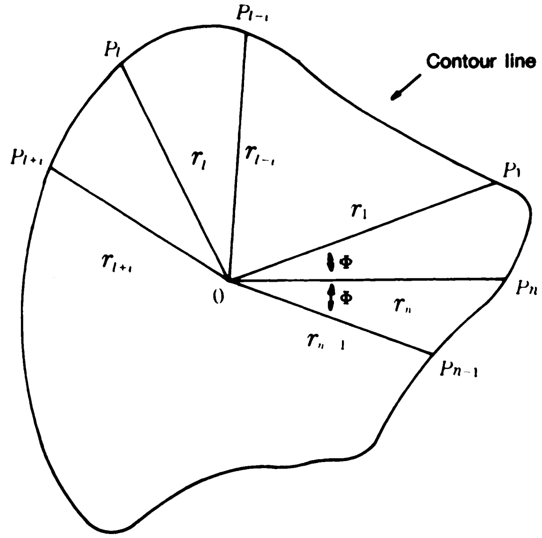
1. The acquisition of contour data from each image has to be carried out under a fixed condition shown in Fig. 2A for the accurate classification and the comparison of many images. By the following rules, the structural data of contour line is represented by points P_l (l = 1,2,3. . . . ,n : n = 360/Φ), Φ is a fixed angular interval, on the contour part. The origin $0(x_0,y_0)$ is set arbitrarily in the image, and the point P_l is any one of points where the maximum intensity in its contour part is found. The other points P_l are plotted as points with the maximum intensity on individual intersected line segments. These line segments are radially drawn from the origin at every fixed angular interval Φ. Then, the length r_l (l = 1,2,3,. . . . ,n) from the origin to P_l is measured.

2. Radioisotope images have many different sizes and shapes even if the processed images are normal. The difference between the size of the abnormal and normal image is also important in medical diagnosis; however, since this paper only discusses a method for the detection of defects in contour part, the length of r_l is normalized by the maximum value of r_l in each image.

3. The origin $0(x_0,y_0)$ and the points P_l $(x_l,y_l$ obtained in the polar coordinate system (r,Θ) by (2) above, are converted into their respective rectangular coordinate system (x,y).

$x_l = r_l^n \cdot \cos\Theta_l + x_0$, $y_l = r_l^n \cdot \sin\Theta_l + y_0$ (1) Where $\Theta_l = l \cdot \Phi$ and $r_l^n \cdot$ is normalized value of r_l.

4. Subsequently, the averaged points, P_{m1} (x_{m1}, y_{m1}) and P_{m2} (x_{m2}, y_{m2}) of N points (N = 1,2,3,. . . .) on both sides of P_l are calculated by the following equations. (See Fig. 2B.)



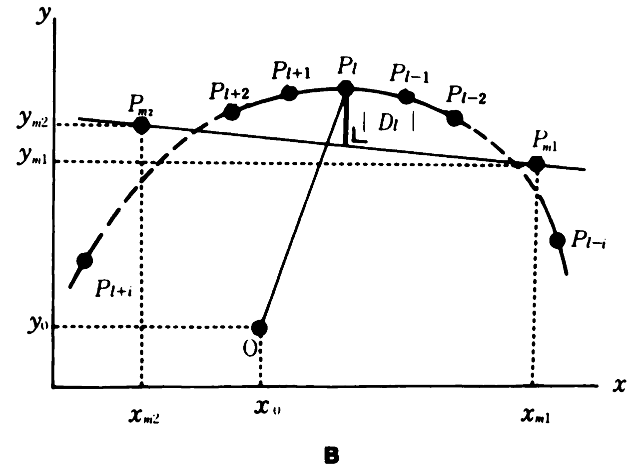


FIGURE 2
Acquisition rule for contour data (A) and definition of distance D_l for quantitative evaluation of convex and concave structure of contour line (B)

$$x_{m1} = \frac{1}{N}\sum_{i=1}^{N} x_{l-i}, \quad y_{m1} = \frac{1}{N}\sum_{i=1}^{N} y_{l-i} \tag{2}$$

$$x_{m2} = \frac{1}{N}\sum_{i=1}^{N} x_{l-i}, \quad y_{m2} = \frac{1}{N}\sum_{i=1}^{N} y_{l-i} \tag{3}$$

This geometrical averaging has a role of the smoothing, which detects different size of defects and eliminates the background noise.

5. Finally, a convex and concave structure is given quantitatively by the distance, D_l, of a line drawn perpendicularly from the point P_l to a straight line connecting two points, P_{m1} and P_{m2}. The distance D_l is calculated in accordance with the following equation.

$$D_l = \frac{[(y_{m2} - y_{m1})/(x_{m2} - x_{m1})] \cdot (x_{m1} - x_l) + Y_l - y_{m1}}{[(y_{m2} - y_{m1})/(x_{m2} - x_{m1})]^2 + 1} \tag{4}$$

The value of the D_l is used to characterize the curvature of the contour line. Discrimination between the convexity and the concavity is represented by the sign of the distance D_l expressed by the location of three points, P_l, P_{m1} and P_{m2}. For example, if the location of P_l is closer to the center of the image than the straight line given by connecting of P_{m1} and P_{m2}, then it is recognized as a convex structure. Conversely, it is defined as a concave structure. The magnitude of the convexity and the concavity is represented by the absolute value of distance D_l, $|D_l|$. Furthermore, since the distance D_l can be expressed without x_0 and y_0 term, the origin can arbitrarily be set within an individual image. It can be verified by substituting the Eqs. (1) through (3) into Eq. (4).

PROCESSING RESULTS

Figure 3 shows the processing results of abnormal and normal images, where the values of N are 3 and 10. The degree of the fixed angular interval Θ is 2 for each image. This value is decided in consideration of the total resolution of the gamma camera. In the figure, the distance D_l is represented by a length of a radially extended straight line from the origin. In this figure, the absolute value of the D_l is superimposed on its contour line indicated by P_l for the evaluation of this method. The indicated length of D_l is magnified 10 times the calculated value of D_l which represents the contour structure at a point P_l. A complete contour structure of an image is formed by integrating each D_l at every l. The radii of external and internal circles shown a broken line are 1.0 and 0.5 of the maximum value of r_l from the origin. It can be seen that the D_l corresponds to the contour structure, and it has large values where the magnitude of the convexity or the concavity is large. In addition, D_l shows the feature of the large curvatur with increasing N, because N has a role of the smoothing operation.

The distance D_l in the normal case (A) has three peaks at I, II, and III as shown in Fig. 3. Each peak indicates a large convexity in the contour line. Furthermore, D_l has very small values between I and II, and II and III, from these characteristics, it suggests that these regions have no convex or concave structure caused by SOL. On the other hand, in these two regions, the distance D_l in (B) has large irregular convex and concave structure at points A, B, and C in Fig. 3. Accordingly, the radioisotope image with contour structure which does not have an evidently large D_l at I, II, and III or indicates large D_l in the region between I and II or II and III is recognized as the abnormal liver.

DISCUSSION

From the processing results of the test patterns, it could be confirmed that if D_l has a large value, zero or a constant value, then the contour line is represented by large convex or concave structure, a straight line or a circle respectively. (See Appendix.)

The detection of a contour line of a radioisotope image

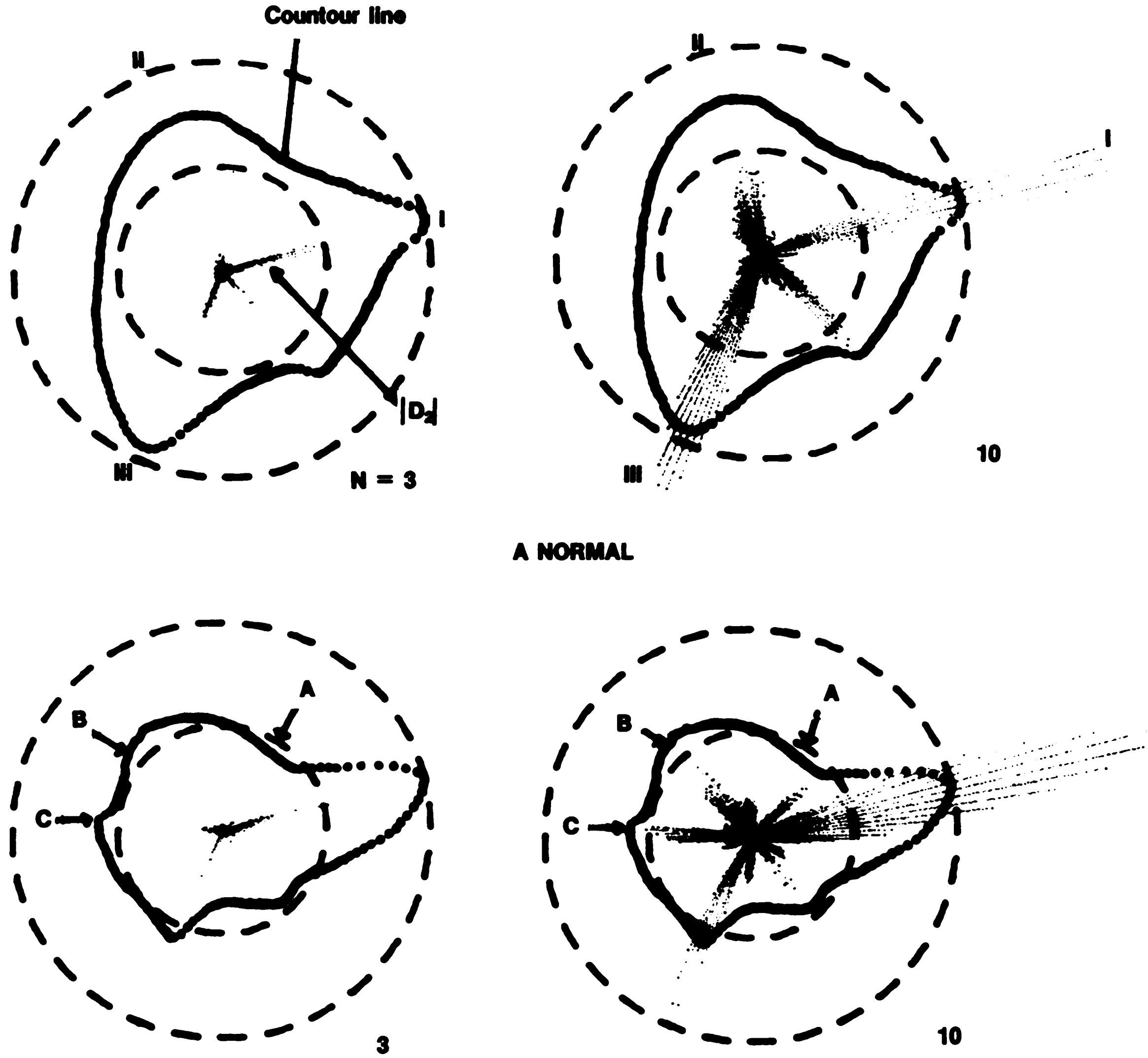


FIGURE 3
Processing results of normal and abnormal case as shown in Fig. 1. Distance D_l in normal case (A) has three peaks at I, II and III. On other hand, abnormal case (B) shows large irregular structure at A, B, and C, and it does not have evidently large D_l at I, II and III

is very important in this method. The accuracy of the contour detection affects directly the detection of the contour structure. For the elimination of the quantum noise, the smoothing operation and averaging by N are used. To the clinical application, some techniques by subtraction method for background noise (*8*) and interpolation by the spline curve for the detection of the contour line is also available in our preprocessing.

It is necessary to set an origin in each image for the comparison of many images. In former studies, the setting of the origin has been very complicated, because it could not be uniformly set at fixed location caused by many different sizes and shapes of images. For example, it was set at the center of gravity. However, the present method allows the origin to be arbitrarily set in each image, since D_l is not affected by the location of the origin. Therefore the calculation for the feature extraction can be very simple, and the D_l has no error caused by different locations of the origin.

In the acquisition rule of contour data, the fixed angular interval Θ defined a fixed value. However, if the contour line is constructed by very complex structure containing sharp rises and falls, then the point P_l can not easily be defined by this data acquisition rule. In that case, it is better that Θ is partially varied depending upon the contour structure. On the other hand, the optimal value of N should be decided in consideration of the minimum size of defects displayed on radioisotope image, the total resolution of using gamma camera and Φ. From processing results of six different cases, three normal and three ab-

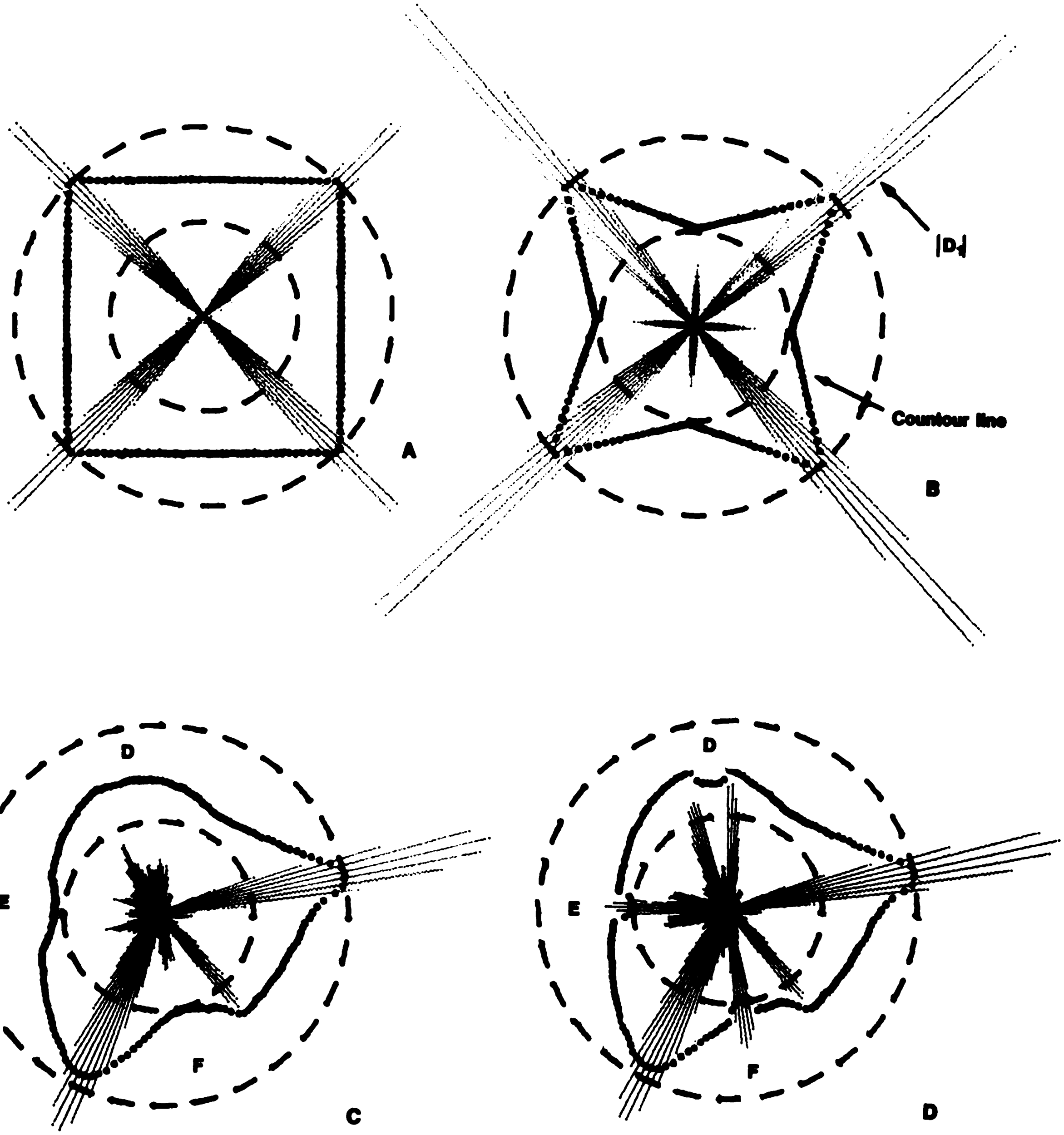


FIGURE 4
Processing results of test patterns and phantoms

normal, we suggest that N is 6 for the detection of irregular contour structure caused by SOL and 13 for global liver deformation.

CONCLUSION

This paper describes a new image processing method for the extraction of convex and concave structures in the contour line of the radioisotope image of human liver. In this method, the contour structure is denoted by the distance D_l, that is, the sign of D_l indicates the discrimination of the convexity or the concavity and the absolute value of D_l indicates quantitatively the amplitude of these structures. The distance D_l corresponds to a convex and concave structure of the contour line. Furthermore, the differences of contour structure between normal and abnormal livers can be clearly expressed by the D_l. Thus, diffuse liver diseases are not sufficiently detected by our proposed method. But this method can evaluate quantitatively contour structure, and detect SOL as abnormal contour structure.

FOOTNOTE

*Nuclear Chicago PHO Gamma III camera, Siemens Medical Systems, Iselin, NJ.

APPENDIX

Processing results of test patterns and phantoms

Figure 4 shows processing results of test patterns (a),(b) and phantoms of artificial two different defects (c),(d). These artificial defects are added to the normal contour line shown in Fig. 3(A) at D, E and F. The shape of the artificial defects is a half of ellipse which the depth and the width are 5% of the maximum length of r_l and 19 points on the contour line (c), and 10% and 7 points (d). In these results, the value of N is 10. From the processing results, the distance D_l indicates quantitatively that the square has four convex structures, and the cross has four convex and four concave structures. At the four vertexes, the D_l of the cross are larger than the D_l of the square. It implies that the cross has more convexity structure at the vertexes. On the other hand, the distance D_l at D, E, and F is larger compared with the processing result shown in Fig. 3A. From these results, it suggest that the distance D_l can indicate quantitatively the contour structure.

REFERENCES

1. Loken MK, Ponto RA, Kush GS : Quantification of image studies obtained with a scintillation (Anger) camera. *Radiology* 95:505–516, 1970
2. Clair Neill GD St, Hutchinson F : Computer detection and display of focal lesions on scintiscans. *Br J Radiol* 44:962–969, 1971
3. Cole AZ, Croft BY, Brickley JJ, et al. : Evaluation of digital image enhancement techniques for liver scintigrams. *Phys Med Biol* 27:63–72, 1982
4. Konishi K, Okuyama T, Suzuki S : A numerical analysis on photo-scintigraphic outline pattern of liver with Au-198 colloid. *Nipp Act Radiol* 34:752–762, 1974
5. Maeda T, Ogawa F, Okabe H, et al. : Computer-aided diagnostic system of diffuse liver diseases using scintiscanning; Application of linear discriminant function. *Nipp Act Radiol* 36:636–644, 1976
6. Cahill PT, Ornstein E, Ho SL : Edge detection algorithms in nuclear medicine. *IEEE Trans* NS-23:555–559, 1976
7. Lev A, Zucker SW, Rosenfeld A : An iterative enhancement of noisy images. *IEEE Trans* SMC-7:435–442, 1977
8. Goris ML, Daspit SG, Mclaughlin DP, et al. : Interpolative background subtraction. *J Nucl Med* 17:744–747, 1976