Processing of Liver Scan by an Electronic Computer: Clinical Experience

Kikuo Machida, Akira Akaike, Sanshin Hayashi, Tsutomu Watari, Kazuyuki Oyama and Hiroshi Yasukochi

Department of Radiology, University Branch Hospital, Faculty of Medicine, University of Tokyo, Mejirodai 3-28-6, Bunkyo-ku, Tokyo 112

肝シンチグラム電算機処理の臨床的経験

東大分院放射線科

町田喜久雄**　赤池　陽　林　三進

亘理　勉***　小山　和行　安河内　浩*

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通常の肝シンチグラム記録時に，同時に作成した紙テープを電算機に処理させ，平滑化などの処理を行い比較検討を臨床例について行なつた．

平滑処理を行なつたもの，行わないもの，オリジナルのシンチグラム等の間で比較を行なつた．平滑化処理は像を著しく改善し，実際の肝のＲＩ分布を，より忠実に表現しているように思われた．

欠損像の診断においても，われわれの検討した条件では，平滑像の方が見やすくなつており，その際，非連続的なＲＩ濃度の変化が，診断上有力な手がかりとなることを確認した．

また肝脾のカウントのレベル比が疾病診断の手段となりうる可能性も検討した．

Abstract

Liver scans were recorded in paper tapes simultaneously with routine scintigrams. By using these tapes the scintigrams were processed with TOSBAC 40 time-sharing system computer. The liver scintiscans were recorded with a Toshiba scintiscanner (ϕ 3 inches) with a 37 hole collimator (distance to focus, 10 cm), after intravenous administration of ^{99m}Tc or ^{198}Au colloid to the patient.

The quality of images was compared among original photoscan, non-smoothed digital computer display, and the smoothed digital display. By smoothing the original, the image of liver scans was im-

* 現　越谷市立病院放射線科
** 現　東大病院放射線科
*** 現　独協医大放射線科

proved markedly and appeared to be a more faithful expression of the rasioisotope concentration in the liver, anatomically and physiologically. The computer displayed each point in 10 different marks according to the number of counts, which enabled quantitative recognition of the radioactivity of the point. Thirteen-point smoothing, five- and nine-point smoothing were performed.

In detecting the filling defect it is concluded that the incongruity of the concentration of a radioisotope is an important factor and the contour scan could play a role in making diagnosis. Further, the integral counts of the liver as well as splenic area were calculated, and the ratio between these two counts was compared. The ratio of the each level of the count between liver and spleen was also calculated.

Introduction

In 1967, Benna et al.[1] reported the usefulness of digital scanning compared with photoscanning, and the same kind of investigations were made by Borkat[2] and by St. Clair Neill[3].

Recently, we developed a method for processing the image of rectilinear liver scan by a small electronic computer (Tosbac 40, time-sharing system computer, 64KB), which is connected to the terminal apparatus in our department by a commercial telephone line permitting us to obtain a computer-processed image. We previously reported the clinical usefulness and significance of a computer-processed scintigram of ^{131}I-macroaggregated albumin lung-perfusion scan[4] and ^{67}Ga chest scintigram[5]. The purpose of this paper is to demonstrate some of our clinical experiences in the computer processing of rectilinear liver scans.

Material and Method

The paper tape was prepared with the apparatus which we reported previously[6][7]. The apparatus consists of sampling circuits, controller, and a tape perforator. The sampling circuits are connected to the Toshiba RDA 206M scintiscanner to gather informations such as scan start signal, line start signal, backline start signal, scan signal, interval signal and count signal. The count signal is obtained from the output of a pulse height analyzer under the control of the interval signal received from a specially designed magnetic switch attached to the shaft of the scanner. The controller has two buffers which have two-word memories and each buffer of two-word memories can receive any number between 0 and 99, and, if the number of output from the pulse height analyzer is larger than 100, the pulse will be decreased automatically to numbers below 99 by the rate-down circuit.

By using these tapes, we processed liver scans with the Tosbac 40 time-sharing system computer connected to the terminal in our department by the regular telephone line, which is located 4 Km away. The anterior scintigrams were obtained with the Toshiba rectilinear scanner (3 inches) with a 37-hole collimator (distance to focus, 10 cm) after intravenous administration of 2–3 mCi of ^{99m}Tc colloid or or 300 μCi of ^{198}Au colloid to the patient with liver disease who visited our department. The principle of recording scans in the paper tape has been reported previously[4]. By using these tapes we analyzed liver scans by the computer, and the non-smoothed digital images and several smoothed digital images were constructed by the computer and compared with each other, and also to the original scintiphotos. The smoothed points were calculated from the following formula (Fig. 1).

$$A_{7s} = \{A_7 \times 10 + L_1\ (A_6 + A_8) + L_2\ (A_3 + A_{11}) + M\ (A_2 + A_{10} + A_{12} + A_4) + N_1\ (A_5 + A_9) + N_2\ (A_1 + A_{13})\} \div \{10 + 2\ (L_1 + L_2 + N_1 + N_2) + 4M\}$$

$$A_1$$
$$A_2\ A_3\ A_4$$
$$A_5\ A_6\ A_7\ A_8\ A_9$$
$$A_{10}\ A_{11}\ A_{12}$$
$$A_{13}$$

Fig. 1. The matrix element of an image.

The condition of smoothing can be altered by changing the values of L1, L2, N1, N2, and M. The maximum count level as well as minimum count level was also changed. This procedure also markedly changed the character of the digital images.

Each level of the count in the liver area and splenic area was also computed and the integral counts of both fields were also obtained. Both digital and photoscans were recorded in 30 patients for whom liver scans were considered appropriate. Scan diagnoses were normal or consistent with hepatitis in 10 cases, liver cirrhosis in 12 cases, and filling defects in 8 cases.

Results

The digital scintigram expressed the concentration of a radioisotope quantitatively in contrast to photoscintigrams. Furthermore the problems of saturation or distorting of film response were excluded.

In comparing the smoothed digital scintigram with non-smoothed digital scan, the smoothed and isocount contour scan revealed a more congruous distribution of a radioisotope within the liver, which seemed to be more faithful to the radioisotopic concentration in the liver, anatomically and physiologically. Some of the clinical cases are described below.

Case 1. No. K 2747. Y.M., 57-year-old male. Clinical diagnosis: Liver tumor.

Original liver scintiphoto is shown in Fig. 2(a), which reveals a filling defect in the upper part of the liver.

Digital diplay without smoothing process is shown in Fig. 2(b), in which the filling defect is seen in the same part. In Fig. 2(c) the digital scintigram with 13-point smoothing is shown. The distribution of radioisotope or the isocount contours became smooth, but their incongruous arrangement in the upper area is revealed quantitatively. This incongruous arrangment is definitely shown in the contour digital scitigram [Fig. 2(d)]. This is a clinical example of making the filling defect clearer and allowing us an easy perception of the defect in the liver.

Case 2. No. 9092. S.T., 60-year-old female. Clinical diagnosis: Esophageal cancer and radiation hepatitis.

The original photoscintigram and the digital scintigrams processed by the computer are shown in Fig. 3.

The liver photoscintigram [Fig. 3(a)] was performed after Telecobalt radiation therapy of 6000 rads for esophagus cancer. The large filling defect is noted in the liver due to radiation injury.

The digital non-smoothed scan is shown in Fig. 3(b), 13-point smoothed scan in Fig. 3(c), and 5-point smoothed scan in Fig. 3(d). The 13-point smoothed digital scintigram reveals a homogeneous

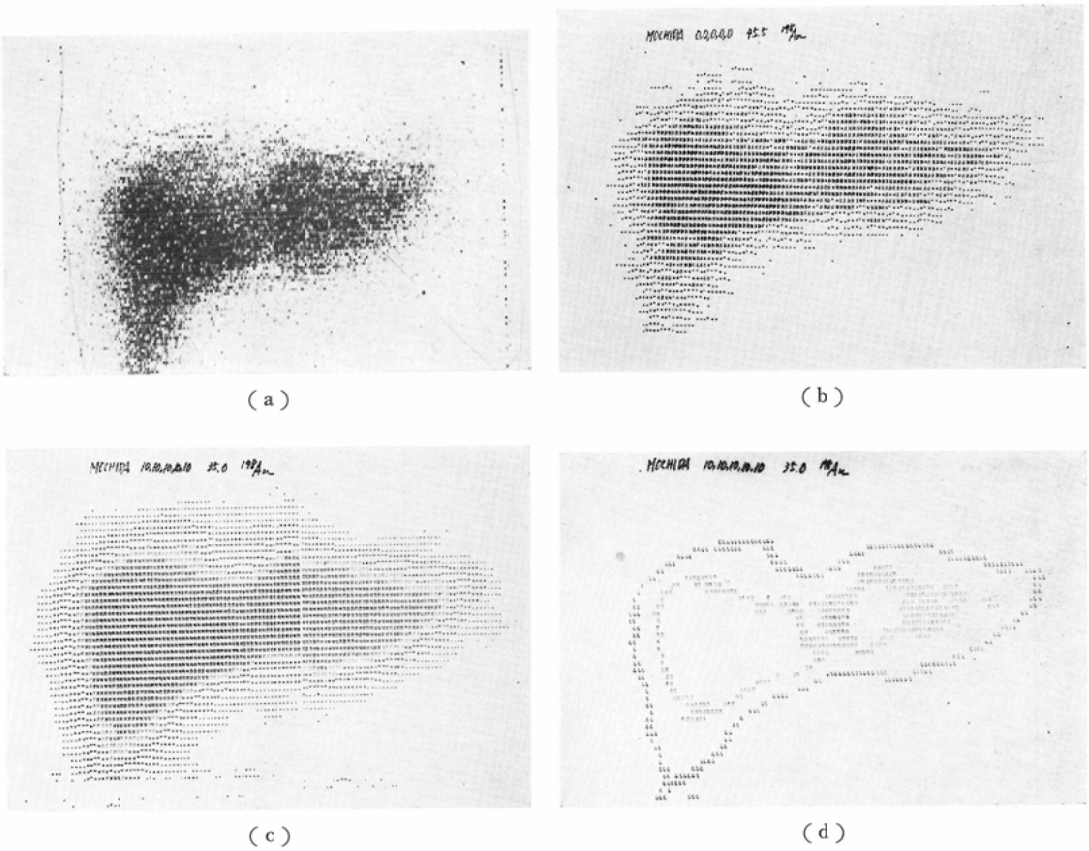


Fig. 2. Case 1. Clinical diagnosis: Hepatic tumor.

Original photoscan (a), non-smoothed computer display (b), 13-point smoothed computer display (c), and its selected isocount isocount contour scan (d), are shown. Note the incongruity in the upper middle area of the liver, which is demonstrated more clearly and quantitatively in the selected isocount countour display. Non-smoothed display reveals statistical fluctuation of the count.

distribution of radioactivity within the liver, and the contours of each level of the count are more smooth and clearer than the original. The 5-point smoothed scintigram show a less smooth quality than that of the 13-point smoothed scan. The isocount contour clearly shows the filling defect. The 13-point smoothed scintigram expressed by numbers is shown in Fig. 3(e), which enables us to determine the quantitative concentration of the radioisotope within the liver more easily. This case is another good example of a computer-assisted digital expression of the filling defect.

Case 3. No. K2413. M.K., 50-year-old male. Clinical diagnosis: Normal.

Original liver scintiphoto is shown in Fig. 4 (a), and the digital outputs are shown in Fig. 4 (b,c). Smoothed computer digital display reveals a congruous distribution of the radioisotpe within the liver in contrast to Case 1 and 2, and although a filling defect was suspected initially in the middle of the liver, liver tumor was not revealed eventually.

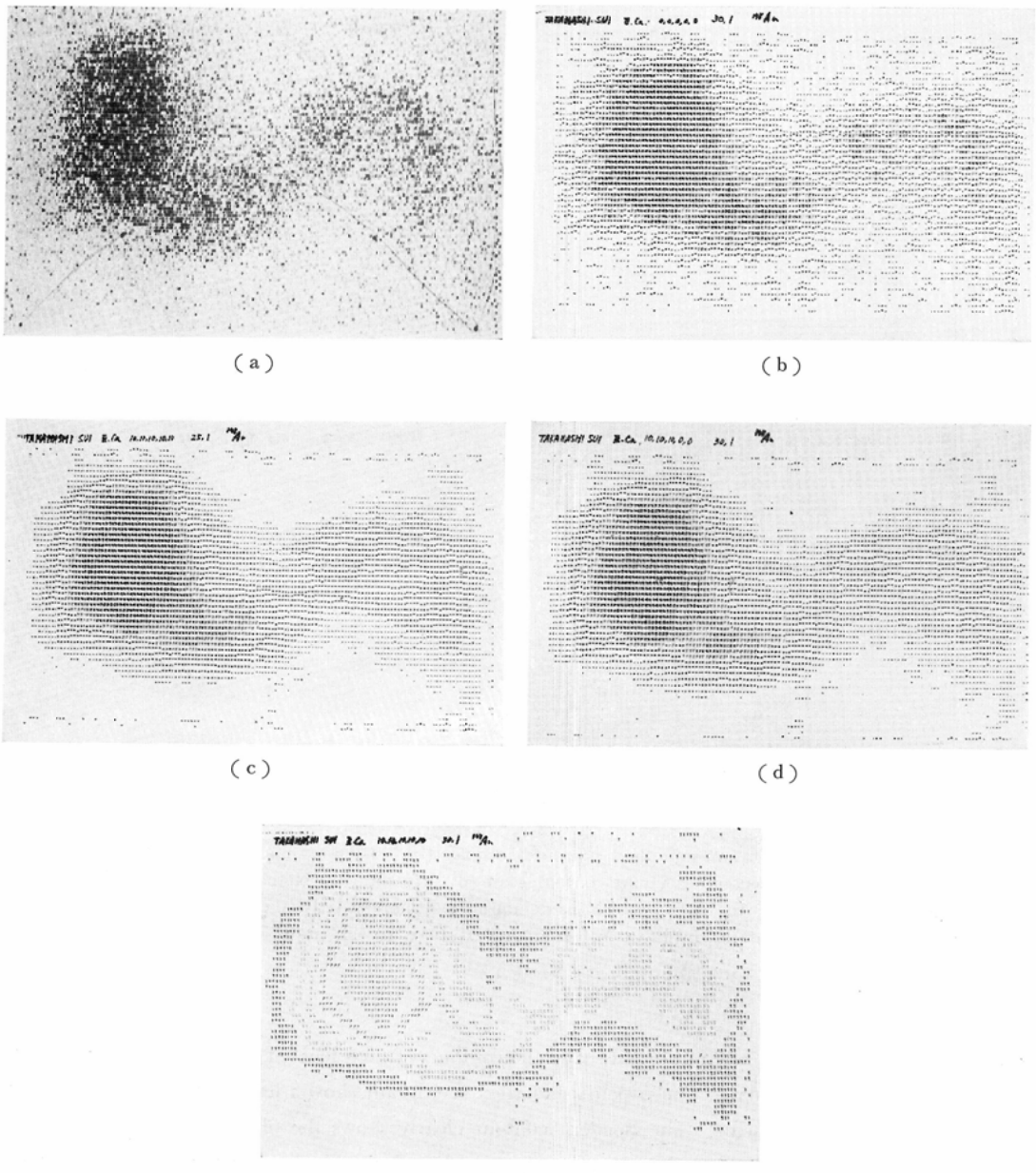
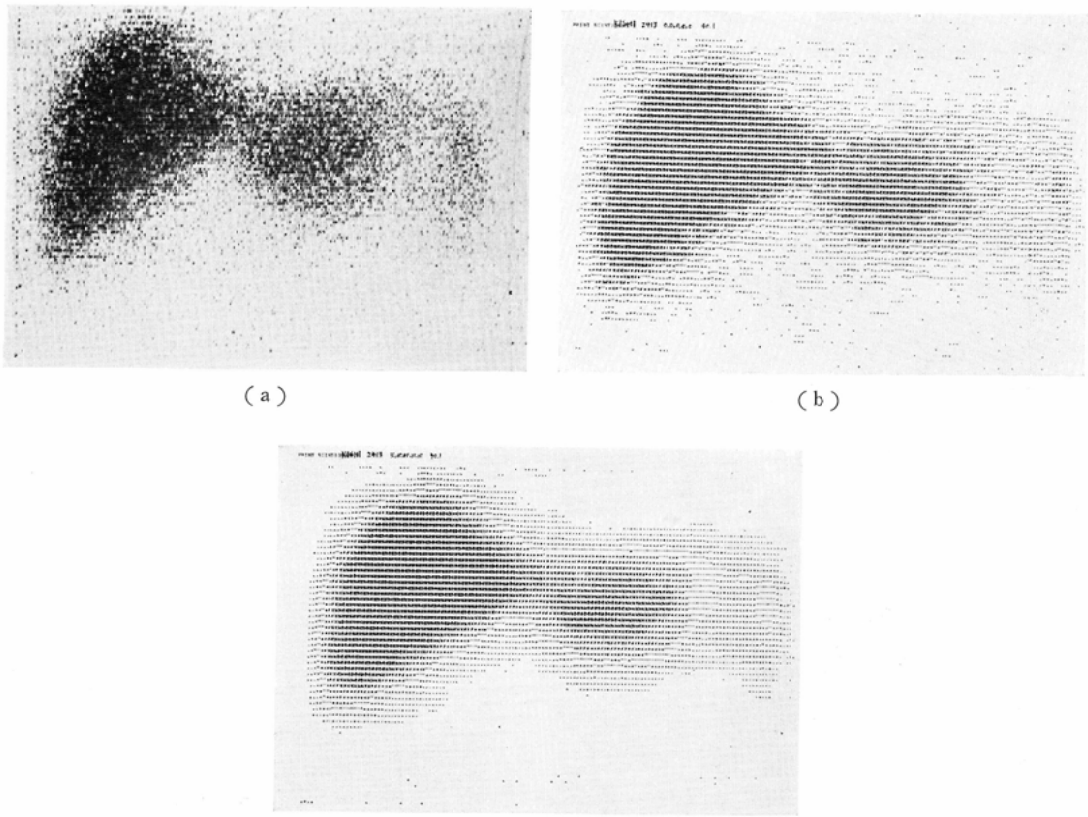


Fig. 3. Case 2. Clinical diagnosis: Esophageal cancer and radiation hepatitis.

Original photoscan (a), non-smoothed computer display (b), 13-point smoothed computer display (c), 5-point smoothed computer display (d), and 13-point smoothed selected contour display (e) are shown. Note the square filling defect in the middle part of the liver consistent with radiation field, and discrete incongruity of radioisotope concentration demonstrated quantitatively especially in (c), (d), and (e). In comparing 13-point smoothed with 5-point smoothed scans, the arrangement of radioisotope concentration is more smooth in the former than in the latter. Non-smoothed display shows dispersion of the concentration for statistical reason.



(a) (b)

(c)

Fig. 4. Case 3. Clinical diagnosis: Normal.

Original photoscintigram (a), non-smoothed computer display (b), and 13-point smoothed computer display (c) are depicted. The filling defect was initially suspected in the middle of the liver, but smoothed computer display revealed congruous distribution of the radioisotope. The liver tumor was not found eventually.

Case 4. No. 17577, E.N., 78-year-old male. Clinical diagnosis: Chronic Hepatitis.

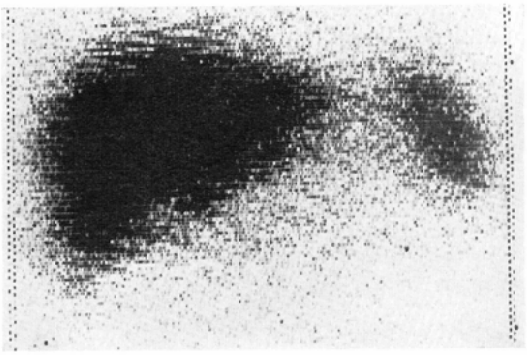
The original liver photoscintigram and the digital scintigrams processed by the computer are shown in Fig. 5.

The original scintigram reveals homogeneous uptake of radioisotope within the liver and enlarged spleen. No filling defects are observed [Fig. 5(a)].

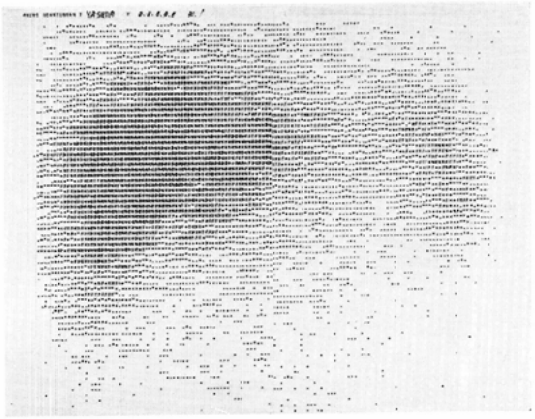
The original digital scintilgram is shown in Fig. 5(b). The concentration of radioactivity at each point is expressed with 10 different sets of printing characters which would give 10 different concentration of printing letters to the radiologist's eyes. The 9-point smoothed digital scintigram and 13-point smoothed scintigram are shown in Fig. 5(c) and Fig. 5(d), respectively. The 13-point smoothed scintigram reveals a homogeneous distribution of radioactivity within the liver quantitatively, and the borderlines of each level of the count are more smooth and clearer than the original scintigram. The 9-point smoothed scintigram shows the same quality as the 13-point, but the effect of smoothing is weaker than those

of the 13-ppint smoothed.

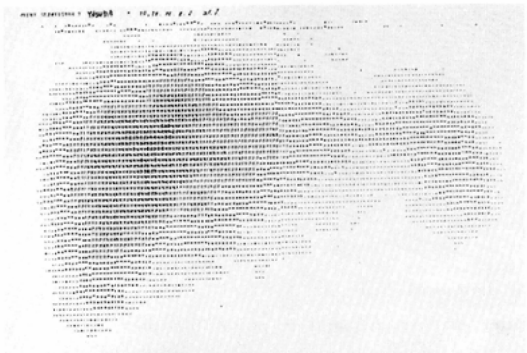
The computer devides each point between maximum and minimum counts which are determined



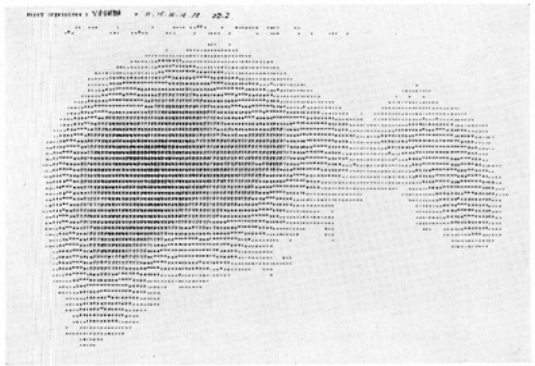
(a)



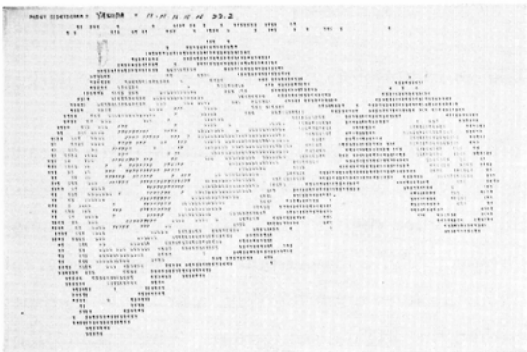
(b)



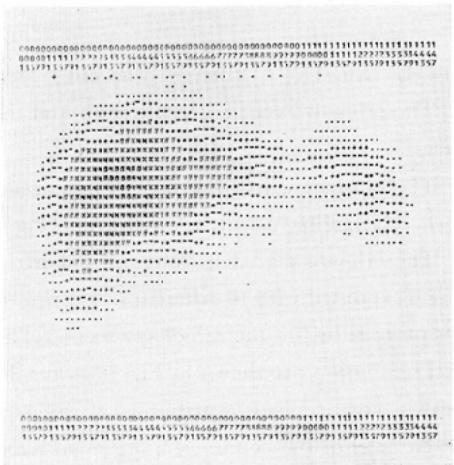
(c)



(d)



(e)



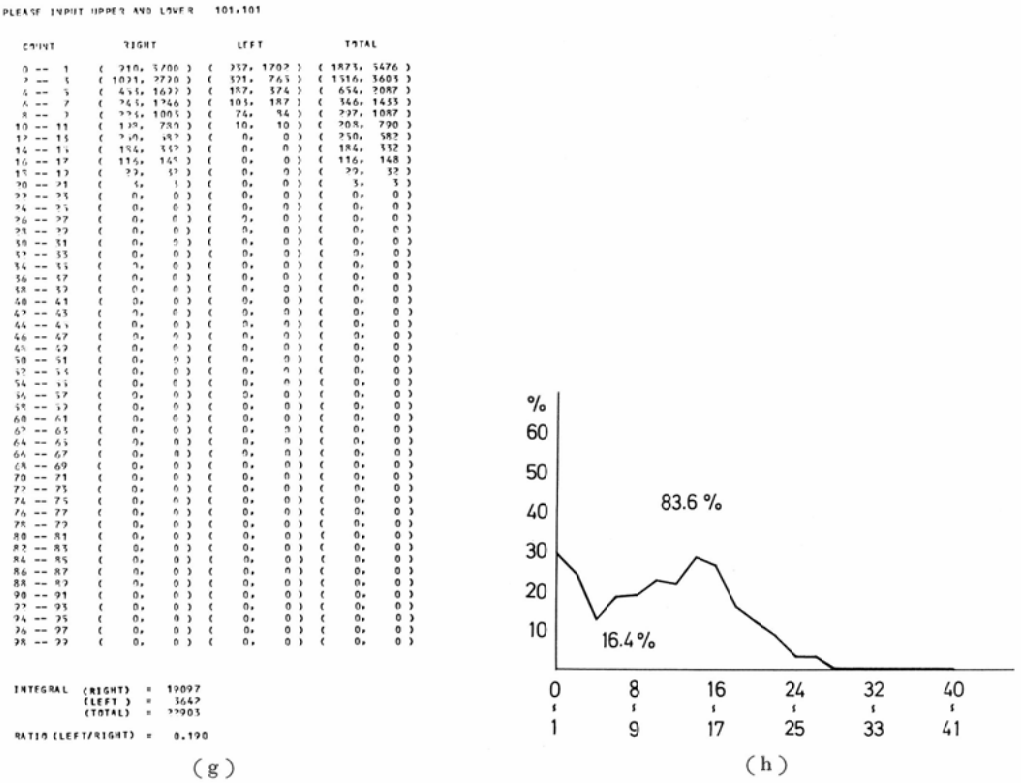
(f)

previously into 10 grades according to the number of counts. When we set the maximum count lower, the area of high concentration becomes larger.
count becomes larger and more simplen.

By the use of the seperating program, a minified scintigram of one-quarter the original size, is printed out with coordinates of a number of three figures in the upper and lower margins [Fig. 5(f)]. By choosing numbers of the coordinate, the computer prints out the frequency distribution which shows the number of the counts of each level in the left and right areas separated by a line connecting the selected upper and lower numbers [Fig. 5(g)].

The first column in the table gives the level of the counts. In the second column, the two sets of parenthesized figures are the number of areas in each level (former) and the accumulated number of the areas above the level (latter). The third are those of the left, and the fourth is the total of left and right numbers.

Finally integral counts, CiNi, where Ci is the level of the counts and Ni is the number of the area of the count of Ci, and its raio between left and right are calculated. The change in the ratio between



(g) (h)

Fig. 5. Case 4. Clinical diagnosis: Chronic hepatitis

Original photoscintigram (a), non-smoothed computer display (b), 5-point smoothed display (c), 13-point smoothed digital display (d), and the isocount display (e) are shown. Half-sized digital display having a coordinate to separate the scintigram and the calculated counts of right (liver) and left (spleen) area (f) are shown. Change in the ratio against the level of the count is depicted (g and h). The integral count is 83.6% in the liver and 16.4% in the spleen.

liver and spleen according to the level of the count is illustrated in Fig. 5(h). The integral count of the liver is 83.6% and at the spleen is 16.4%.

Case 5. No K2969. H.I., 34-year-old male. Clinical diagnosis: Liver cirrhosis.

Original scintiphoto is shown in Fig. 6(a). Liver is atrophic, and bone marrow and enlarged spleen are visualized. All these are typical features of liver scan in liver cirrhosis.

Digital computer diaplays are shown in Fig. 6(b) and (c). After smoothing, the contour of the isocount area is arranged more smoothly, and bone marrow and spleen are revealed clearly and quantitatively.

The relationship between the level of the count and the ratio between liver and spleen is depicted in Fig. 6(d). In comparing with that of Case 4, the shape of the curve is quite similar so that the ratio between the liver and spleen and curve analysis seem to be sometimes useless in differentiating liver cirrhosis from chronic hepatitis. Characters such as the demonstration of bone marrow should be added to the criteria for the diagnosis of liver cirrhosis, as is widely known.

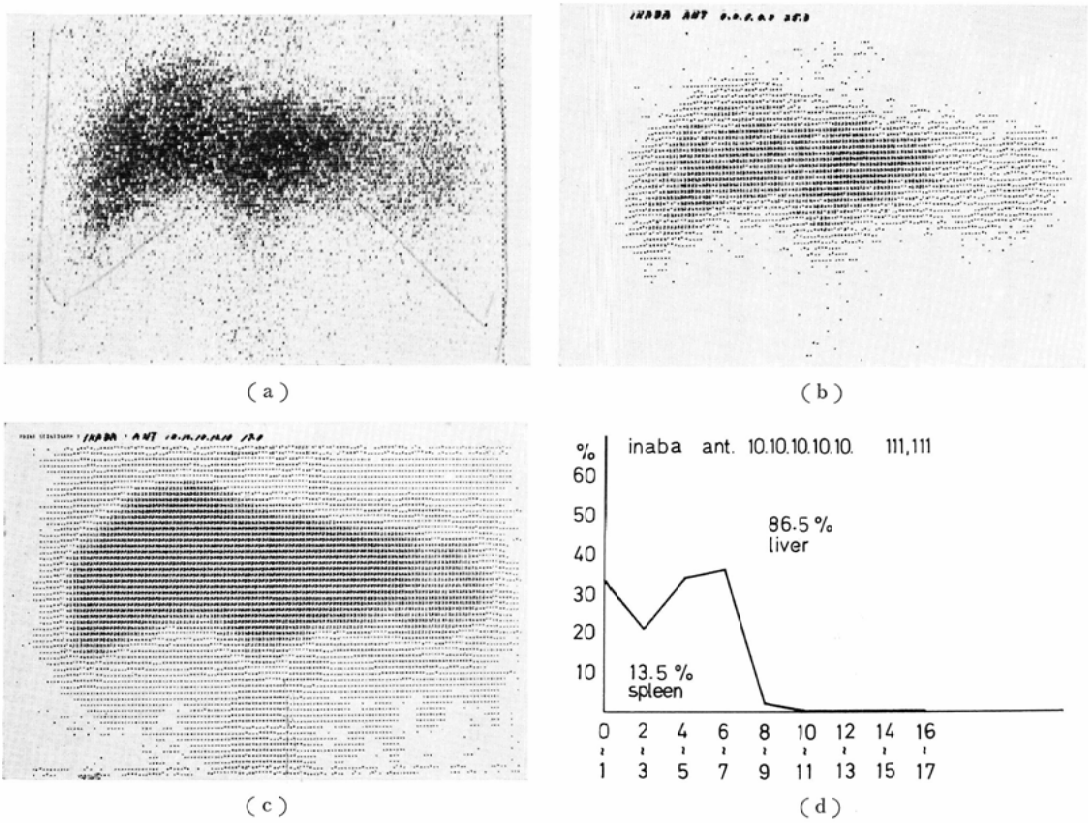


Fig. 6. Case 5. Clinical diagnosis: Liver cirrhosis

Photoscintigram (a), non-smoothed computer display (b), and 13-point smoothed computer display (c) are shown. Note the typical pattern of liver cirrhosis, and the appearance of spleen and bone marrow. The uptake of isotope by the liver and and the isocount contour are more congruous in smoothed display than in non-smoothed. Change in the ratio against the level of the count is shown in (d). Note almost the same pattern as Case 4, chronic hepatitis.

Discussion

Benna[1], Borkat[2], and St. Clair Neill[3] reported that the computer processing of a clinical scintigram is useful, and the latter especially pointed out that a photoscan without quantitative support must be classed as equivocal and that it is necessary to express the distribution of a radioisotope quantitatively.

When we used the liver scan in detecting a filling defect by comparing a computer display with the original scintiphotoas in Cases 1, 2, and 3, we have reached the same conclusion that the computer display with a quantitative expression of radioisotope gives the radiologist a more confirmative information objectively whether the filling defects are present or not. In making a diagnosis, it is important to know if the distribution of radioactivity is congruous or not as reported previously[1]. In Cases 1 and 2, whose liver scan revealed incongruous distribution of a radioisotope, it was easy to diagnose the filling defect within the liver, whereas in Case 5, whose liver scan revealed a congruous distribution of a radioisotope, presence of a filling defect within the liver was denied.

Our way of recording the liver scan has the advantage of greater dynamic range. In contrast to photoscintigrams, it makes possible to express the radioisotope distribution over a wide range of counting rates without the problems of saturation or distorting the film response. The limited dynamic range offered by a scintiphoto is at best two orders of magnitude and has been shown to be a self-degenerative display because the human eye is less able to detect a difference in optical density within increasing density above 1.5, further indicating the advantages of a quantitative scan mode in displaying such data[1].

Isocount contours, plotted by the computer, helped the interpretation of the photoscan. They indicate lesions when they are irregular, widely separated, or occur in an incongruous order with normal anatomic gradients[1]. Our data also supported these conclusions.

The change in ratio of the counts between the liver and spleen is of interest in the case of hepatic diseases. It is generally accepted that the increased uptake of a radioisotope in the spleen is a criteria of a hepatosplenic disease clinically. However, in order to differentiate liver cirrhosis from chronic hepatitis by scintigraphy, it is important to know the uptake of a radioisotope within the bone marrow quantitatively, as is shown in Cases 4 and 5.

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