《原　著》

A Proposal of Program for Processing Scintigrams

——Smoothing, Separating, Character Selecting and Display——

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The processing and the analyzing of scintigrams by computer have been widely used especially in the case of scintillation camera[1)~3)]. We have also started these projects for ten years in the treatment of scintigrams by scanner and reported at other places[4),5)]. In this report we demonstrate a program for the treatment of scintigrams by scanner. In this program to avoid the unnecessary economical risks, any non-routine procedures are eliminated from the program.

Scintigram data from scintiscanner (Toshiba 3″) were punched in a paper tape by every 5 mm intervals[6)] and set in a tape reader which is connected by telephone line to TOSBAC-40-TSS in Tokyo University Hospital 4 km apart from our department. The data were treated by the computer under the control of terminal input/output typerwriter which was set in our department and the result was returned to our department through the same input/output typewriter by telephone line and the processed scintigrams were printed out.

The program is usually performed as demonstrated in figure 1. They are initial load, smoothing, selecting character, separating and display. Histograms for number of area in each count level are also printed out before and after smoothing and separating as occasion demand. In addition, any procedures could be passed or returned to any part according to the purpose. The digital scintigram is printed out after all procedures with selected characters for each level, which are composed of one or two superimposed ones.

INITIAL LOAD

The user types in several identification words for computer, which are name of the patient, nucleid and dose used, organ and direction of the scintigram according to the questions typed automatically after the key words which the user uses to set the program. Then the data in tape are memorized from paper tape to the file, and the filed data are analyzed repeatedly until another scintigram removes the data. After the data of scintigram are memorized,

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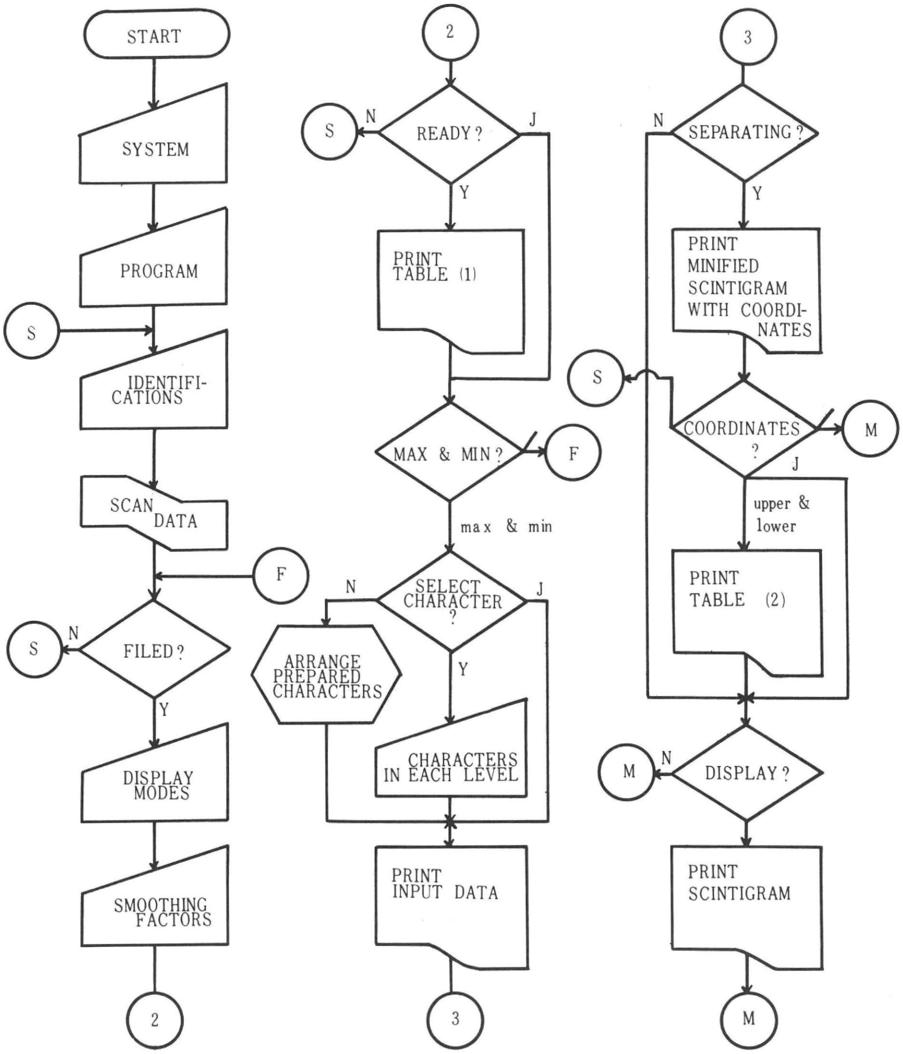


Fig. 1 Rough flow chart of the program.

the informations on pitch size, data channel, reverse mode and rotation modes are typed in after each question.

The pitch sizes of the scanner which mean the width of each row are limited to 2, 4 and 6mm, and on the other hand, the print from scintigram element depends on the area of the characters of the input/output typewriter which is almost 2.5mm×4mm. Because the data from the scanner are punched by every 5mm intervals, the data in each element from the scanner cover 5mm×2mm when pitch size was 2mm, 5mm×4mm at 4mm and 5mm×6mm at 6mm. If the selection of pitch size is 2, the data in the same position of the next row are averaged with the data in original row and replaced as new data while eliminating every two rows, and therefore, the number of the data becomes one half of the original. By this procedure the calculation of the position of characters arc eliminated. These are explained in figure 2. If the data in "i"th row

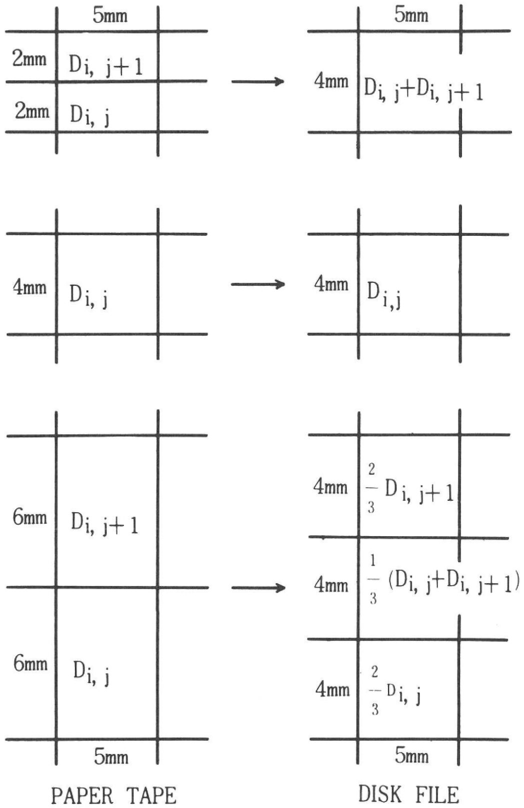


Fig. 2 Schema for explaining the conversion of data from tape to file in computer.

and "j"th data from right end of the row are nominated as $D_{i,j}$, the data in odd rows of $D_{i,j}$ are replaced as $(D_{i,j}+D_{i+1,j})/2$ and the data in even rows are eliminated after new data are created.

If the selections is 6, the data in each row becomes two thirds of the original data $(2D_{i,j}/3)$ and new rows are created and inserted after each odd row whose data are two thirds of the average of two rows that is $(D_{i,j}+D_{i+1,j})/3$. If the selection is 4, the data in the tape are directly used. By these selections of pitch size, any datum of the scintigram in the tape is memorized as an arrangement of 4mm width of rows in the file.

Next, the selection of channel is offered. Because the scanner has two energy channels and the data from each channel are memorized in a tape simultaneously, the selection of channel occurs[7]. If the selection of 1 is done, the data in channel 1 are memorized and if 2, those in channel 2. Unfortunately the program has no capacity to calculate or analyze between these two channels as yet.

The program has a capacity of printing out modes in reverse position and rotating positions of 90°, 180° and 270° as demonstrated in figure 3. If these selections are neglected by typed 'N', the scintigram is printed out as normal position. The reverse mode is useful to read a posterior scan as an anterior view and rotation modes are useful in following separating programs. The reverse mode and the rotation modes can be coupled if necessary.

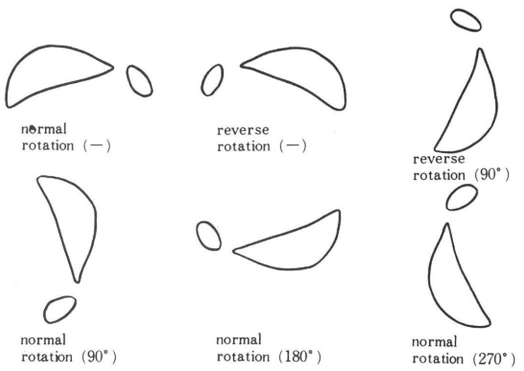


Fig. 3 Modes of rotation and reverse position.

SMOOTHING

For smoothing several methods are reported which could be divided into three main categolies, they are non-weighted average, weighted average and some functional treatment. However, most of them could be represented by variably weighted average method. To cover these methods, the smoothing program was composed of weighed average

$D_{i+2,j+2}$	$D_{i+1,j+2}$	$D_{i,j+2}$	$D_{i-1,j+2}$	$D_{i-2,j+2}$
$D_{i+2,j+1}$	$D_{i+1,j+1}$	$D_{i,j+1}$	$D_{i-1,j+1}$	$D_{i-2,j+1}$
$D_{i+2,j}$	$D_{i+1,j}$	$D_{i,j}$	$D_{i-1,j}$	$D_{i-2,j}$
$D_{i+2,j-1}$	$D_{i+1,j-1}$	$D_{i,j-1}$	$D_{i-1,j-1}$	$D_{i-2,j-1}$
$D_{i+2,j-2}$	$D_{i+1,j-2}$	$D_{i,j-2}$	$D_{i-1,j-2}$	$D_{i-2,j-2}$

⇨

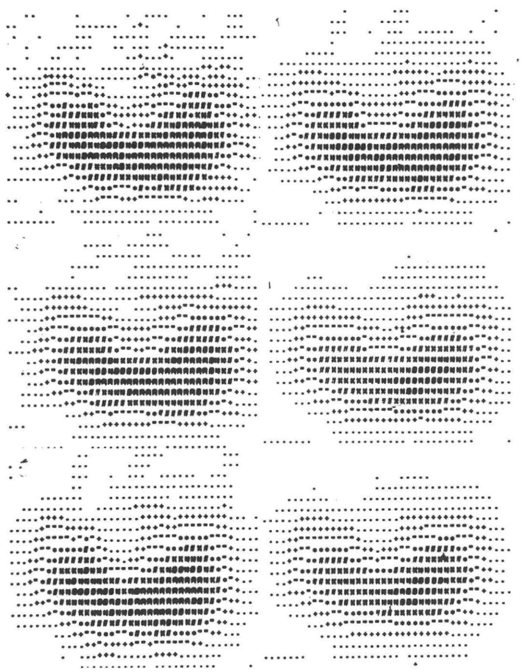
$D'_{i+2,j+2}$	$D'_{i+1,j+2}$	$D'_{i,j+2}$	$D'_{i-1,j+2}$	$D'_{i-2,j+2}$
$D'_{i+2,j+1}$	$D'_{i+1,j+1}$	$D'_{i,j+1}$	$D'_{i-1,j+1}$	$D'_{i-2,j+1}$
$D'_{i+2,j}$	$D'_{i+1,j}$	$D'_{i,j}$	$D'_{i-1,j}$	$D'_{i-2,j}$
$D'_{i+2,j-1}$	$D'_{i+1,j-1}$	$D'_{i,j-1}$	$D'_{i-1,j-1}$	$D'_{i-2,j-1}$
$D'_{i+2,j-2}$	$D'_{i+1,j-2}$	$D'_{i,j-2}$	$D'_{i-1,j-2}$	$D'_{i-2,j-2}$

$$\text{where } D'_{i,j} = [10D_{i,j}+n_1(D_{i+1,j}+D_{i-1,j})+n_2(D_{i,j+1}+D_{i,j-1}) \\ +n_3(D_{i+1,j+1}+D_{i-1,j+1}+D_{i+1,j-1}+D_{i-1,j-1}) \\ +n_4(D_{i+2,j}+D_{i-2,j})+n_5(D_{i,j+2}+D_{i,j-2})] \\ \div(10+2n_1+2n_2+4n_3+2n_4+2n_5)$$

Fig. 4 Schema for explaining the smoothing formula and weights in surrounding points.

of 13 points, where element which consists of 4mm×5mm area in original size is weighed as 10, and the weights of surrounding 12 can be selected manually for any number between 0 and 99. Because the center was weighed as 10, the numbers over 11 are not usually used. When the data of the selected point are $D_{i,j}$, the weights in $D_{i,j-1}$ and $D_{i,j+1}$ are nominated as n_1, $D_{i-1,j}$ and $D_{i+1,j}$ as n_2, $D_{i-1,j-1}$, $D_{i-1,j+1}$, $D_{i+1,j-1}$ and $D_{i+1,j+1}$ as n_3, $D_{i,j-2}$ and $D_{i,j+2}$ as n_4 and $D_{i-2,j}$ and $D_{i+2,j}$ as n_5 as demonstrated in figure 4. In usual manner n_1 and n_2, n_4 and n_5 may have the same weights but in order to check the line smoothing, these weights are prepared to be separated. By these weighting, $D_{i,j}$ is replaced by $[10D_{i,j}+n_1(D_{i,j-1}+D_{i,j+1})+n_2(D_{i-1,j}+D_{j+1,j})+n_3(D_{i-1,j-1}+D_{i-1,j+1}+D_{i+1,j-1}+D_{i+1,j+1})+n_4(D_{i,j-2}+D_{i,j+2})+n_5(D_{i-2,j}+D_{i+2,j})]/(10+2n_1+2n_2+4n_3+2n_4+2n_5)$.

When the smoothing is offered, the user types in, for insrance, "10, 10, 0, 0, 0," for 5 points averaging, "10, 10, 10, 0, 0" for 9 points averaging and "10, 0, 0, 0, 0" for 3 points line



(left upper) non-smoothing, (left middle)3point line average, (left lower) 3points sagital average, (right upper) 5points average (right middle) 9 points average (right lower) 13points average

Fig. 5 Scintigrams in various smoothing weights.

smoothing. If the smoothing is not needed, "N" or "0, 0, 0, 0, 0" is typed in, and if more sophisticated smoothing is offered, any numbers according to the user's desire is typed in. Several scintigrams are demonstrated in figure 5 with different smoothing modes.

After smoothing are selected the histogram of the number of the area in each count level is printed out if necessary. One example is demonstrated in figure 6, in which the numbers in left sided column means the number of counts in one level with intervals of two, in right sided column parenthesized two numbers are the numbers of area within the level limited in left column and the accumulated numbers of the area above the level.

The print out of the histogram could be

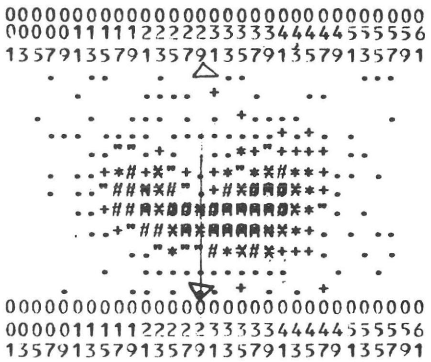
```
START
SCINTIGRAM PROCESSING
NAME OF PATIENT
NUCLEID AND DOSE
ORGAN AND DIRECTION
INPUT DATA FROM DISK ?                  Y
 FILEID ?                               A/SYMTI181
PITCH ?                                 2
CHANNEL OF DATA ?                       1
TURN ?                                  N
ROTATION ?                              N
SMOOTHING ?   (L1,L2,M,N1,N2)           0,0,0,0,0
INPUT   OK ?                            Y


  COUNT               TOTAL

  0 --      1    (    117 ,    744 )
  2 --      3    (    141 ,    627 )
  4 --      5    (    163 ,    486 )
  6 --      7    (     85 ,    323 )
  8 --      9    (     50 ,    238 )
 10 --     11    (     21 ,    188 )
 12 --     13    (     23 ,    167 )
 14 --     15    (     17 ,
 16 --     17    (
 18 --     19             :
 20 --                    .
      :                              )
      :                      ,     0 )
      :              (      0 ,     0 )
           89    (      0 ,     0 )
 90 --     91    (      0 ,     0 )
 92 --     93    (      0 ,     0 )
 94 --     95    (      0 ,     0 )
 96 --     97    (      0 ,     0 )
 98 --     99    (      0 ,     0 )

PLEASE INPUT MAX AND MIN        50,0
```

Fig. 6 Histogram of data after smoothed.

passed to shorten the precedure time.

SEPARATING

When the separating program is selected, a minified scintigram as a quarter in area is printed out with coordinates of 3 descades in upper and lower borders as demonstrated in figure 7. The scintigram consists of characters which represent a datum of 5mm×8mm area



PLEASE INPUT UPPER AND LOWER   029,029

Fig. 7 Minified scintigram with two coordinates explaining the separating program.

in original scintigram. The area of 5mm×8mm has two elements of 5mm×4mm area and each element consists of two characters in life sized digital scintigram. If the "i" is odd number, the area consists of two 5mm×4mm areas of $D_{i,j}$ and $D_{i+1,j}$ is typed by only one character which repesents the data of $D_{i,j}$. In the left side of the character representing $D_{i,j}$ in minified scintigram, the character representing $D_{i,j+1}$ is typed successively, which then represents the areas of $D_{i,j+1}$, and $D_{i+1,j+1}$ and the upper side by the character for $D_{i+2,j}$ which represents the area of $D_{i+2,j}$ and $D_{i+3,j}$ and so on. The coordinates are printed out with the odd number only because each character in the minified scintigram represent 2×2 characters in original scintigram. The even numbers in the original scintigram are represented as the space between two odd numbers. The minified scintigram has two main purposes, which are to know the rough distributions and to shorten the procedure time.

After the minified scan was printed out, two coordinates, upper and lower, which met in both ends of separating line should be typed in. If the ends of line are number in the coodinate number typed, the number is typed in, and if the ends of line are between two typed numbers, even numbers between the two neighbouring odd numbers are typed in. After these procedure, the numbers of area in each level are printed out as a histogram demonstrated in figure 8.

COUNT	LEFT	RIGHT	TOTAL
0 -- 1	(71, 336)	(45, 384)	(117, 744)
2 -- 3	(61, 265)	(78, 339)	(141, 627)
4 -- 5	(76, 204)	(81, 261)	(163, 486)
6 -- 7	(36, 128)	(45, 180)	(85, 323)
8 -- 9	(22, 92)	(25, 135)	(50, 238)
10 -- 11	(5, 70)	(14, 110)	(21, 188)
12 -- 13	(7, 65)	(16, 96)	(23, 167)
14 -- 15	(8, 58)	(8, 80)	(17
16 -- 17	(4, 50)	(6, 72	
18 -- 19	(6, 46)	(	
20 -- 21	(3,		
22 -- 23			
24			
.	.	.	.
.	.	.	.
.	.	.	.
			0, 0)
		0)	(0, 0)
		(0, 0)	(0, 0)
	0, 0)	(0, 0)	(0, 0)
- 95	(0, 0)	(0, 0)	(0, 0)
96 -- 97	(0, 0)	(0, 0)	(0, 0)
98 -- 99	(0, 0)	(0, 0)	(0, 0)

INTEGRAL (LEFT) = 2690
(RIGHT) = 3997
(TOTAL) = 6981

RATIO (RIGHT/LEFT) = 1.485

Fig. 8 Histogram of data after separated.

The first column of the histogram is the level of each two counts: the second column, parenthesized two numbers are the number of areas in each level in the left side of the separating line and accumulated numbers of the area above the level: the third column, these of the right side: and the last column, these of the total, which is the same as in second column of the histogram after smoothing program.

Lastly, accumulated weighed values in both areas and the ratio of them are printed out. The accumulated weighted value means $\Sigma C_i N_i$ where C_i is the level of counts and N_i is the number of area of the count of C_i.

If the comparison between upper and lower regions of scintigram is desired, the print out mode of scintigram must be rotated to 90° as mentioned before and the same procedures are taken place. Of course these procedures could be passed if not necessary as in other procedures.

These methods are already prepared in severl instruments by the use of light pen, but by this method, these procedures could be replaced without using specially designed display systems.

CHARACTER SELECTING

Before printing out the scintigrams, whether they are minified or life sized, the characters for representing the area of 4mm×5mm (in original scintigram) must be selected. For this purpose, the level of scintigram is divided into 10 equall intervals between maximal and minimal counts selected manually. The characters representing each area are the same and each character is representing the following levels. They are 1. (the level above minimal counts +9d), 2. (between minimal counts +9d and +8d), 3. (+8d and +7d), 4. (+7d and +6d), 5. (+6d and +5d), 6. (+5d and +4d), 7. (+4d and +3d), 8. (+3d and +2d), 9. (+2d and +d), 10. (+d and minimal counts) and 11. (under minimal counts), where "d" means the value of (maximal counts−minimal counts)/10. The fractions under decimal point of "d" was counted as a whole number.

The characters representing each level must be one or two and when two characters are selected in a certain level, two characters are typed in one place superimposed on each other. Any characters could be selected including "space", if the characters are arranged on the key board of input/output typewriter.

If the selection of characters is not needed and wanted to be passed, for instance, because of time saving, the characters are prepared for 1(M, Q), 2(O, #), 3(N, =), 4(X, =), 5(#), 6(*), 7(''), 8(+), 9(.) and 10 and 11(space). If the user does not mind to use these characters for each level, he types "N" for asking character selection and if he types "J", the previously selected characters are used. Several scintigrams are demonstrated in figure 9 with different characters for each level and different maximal and minimal counts.

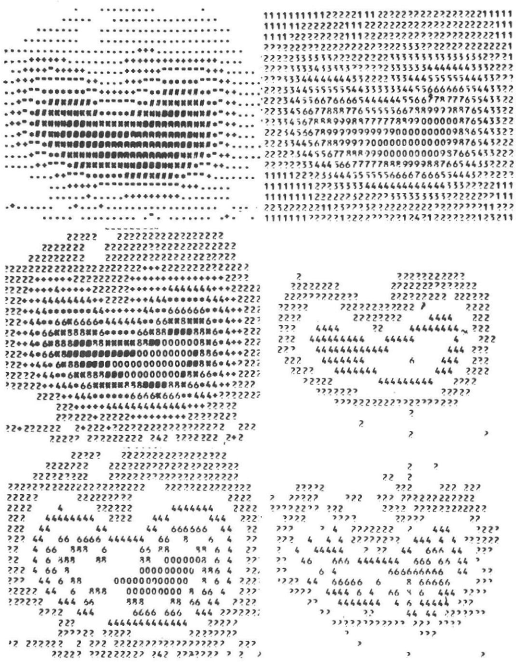


Fig. 9 Scintigrams in various characters and maximal and minimal counts.

DISPLAY

As formerly described, the filed scintigram is composed of elements of 5mm×4mm areas and on the other hands the areas of characters in the input/output typewriter is 2.5mm×4mm, each element must be composed of two characters in life sized scintigram. In printing out the scintigram, characters representing an average of two neighbouring data are inserted after each character representing the data of each element. This means that the element of $D_{i,j}$ is represented by two characters which represent the data of $D_{i,j}$ and $(D_{i,j}+D_{i,j+1})/2$.

The presentation of scintigram is limited to 18.5cm in width which means 74 characters in one row, but it could be extended by dividing scintigram, and in this case the scintigram of 18.5cm width of left side is printed and then

Fig. 10 Display of scintigram whose width is over than 18.5cm (74 characters).

the rest is printed in separate one as demonstrated in figure 10.

Of course, this procedure could be passed as noted in other sections.

DISCUSSION

Here we have reported a program for scintigram processing. The program for smoothing will be useful for routine scintigram readings and the evaluation of smoothing effect[8)-12)], and the separating program will be useful for physiological researches on symmetrical organs just as thyroid, lungs, brain, salivary glands and kidneys[13)]. It is also useful for liver spleen ratio[14)], kidney bladder ratio and so on. The character selecting program will be useful for evaluation of scintigram interpretations according to the emotional changes of density or count rate[15)-21)].

The characteristics of this program are that each part could be passed and also returned to any part without replacing programs for computer which familiarize the users and save the time for preparing.

By this program we are scheduling several projects and they will be reported in the near future.

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文　献

1) 安河内浩：コンピューター利用の現状と問題点．原子力工業，**15** (11)：17～32，1969.
2) Downham, M.C., Evens, R.G.: Economic analysis of scintillation camera usage in nuclear medicine facilities., Radiology, **101**: 643～649, 1971.
3) Rejali, A.M., Friedel, H.L., Gregg, E.C.: Radioisotope scanning with a system for total information storage and controlled retrieval., Amer. J. Roent., **97**: 837～849, 1966.
4) 安河内浩：シンチグラム記録表示装置，シンチグラフィーの基礎と臨床（平松博，久田欣一編）p.73～41，金原出版，1970.
5) 安河内浩，鈴木孝治，河野秀樹：コンピューターによるシンチグラムの診断，癌の臨床，**18**: 238～243, 1972.
6) 安河内浩，町田喜久雄，工村房二，大島統男：簡単な紙テープ穿孔装置について，日本医放誌，**34**: 33～43，1974.
7) Overton, J.R., Heslip, P.G., Barrow, P.A., Jelinek, S.: Dualradioisotope techniques and digital image-subtraction methods in pancreas visualization., J. Nucl. Med., **12**: 493～498, 1971.
8) Brown, D.W.: Digital computer analysis and display of radionuclide scan., J.Nucl. Med., **7**: 740～753, 1966.
9) Mallard, J.R., Corfield, J.R.: A statistical model for the visualization of changes in the count density on radioisotope scanning displays., Brit. J. Rad., **42**: 530～538, 1969.
10) Nagai, T., Iinuma, T.A., Koda, S.: Computer-focusing for area scans., J. Nucl. Med., **6**: 528～530, 1967.
11) Sprawls, Jr. P.: Digital-computer interpretation of radioisotope distribution patterns., J. Nucl. Med., **10**: 618～620, 1969.
12) Yoder, R.D., Evans, M.R., Sweeney, J.W.: Processing picture with computers, an introduction., JAMA, **200**: 1171～1175, 1967.
13) Halko, A., Burke, G., Sorkin, A., Enenstein, J.: Computer aided statistical analysis of the scintillation camera ^{131}I-hippuran regogram., J. Nucl. Med., **14**: 253～264, 1973.

14) Grossman, B.L., Johnson, P.H., Wood, E.H.: Quantitative color scintiphotography with the digital autofluoroscopy in liver examination., J. Nucl. Med., **9**: 135~139, 1968.
15) Benna, R.S., Weber, D.A., Kenny, P.J., Laughlin, J.S.: Digital scanning compared with photoscanning in liver examination., J. Nucl. Med., **9**: 135~139, 1968.
16) Borkat, F., Wiener, S.N.: Ane lectrostatic display for computerized scintiscans., Amer. J. Roent., **117**: 146~152, 1973.
17) Huchinson, F., St. Clair Neil, G.D., Rimmer, A.R.: Line printer display of digital scintiscans., Amer. J. Roent., **113**: 755~764, 1971.
18) Pizer, S.M., Vetter, H.G.: Problem of display in visualization of radioisotope distributions., J. Nucl. Med., **7**: 773~780, 1966.
19) St. Clair Neill, G.D., Huchinson, F.: Computer detection and display of focal lesions on scintiscans., Brit. J. Rad., **44**: 962~969, 1971.
20) Tauxe, W.N.: 100-level smoothed scintiscans processed and procuced by digital computer., J. Nucl. Med., **9**: 58~63, 1968.
21) Weber, D.A., Konny, P.J., Pochazevsky, R., Corey, K.R., Laughlin, J.S.: Linearscan with digital read out., J. Nucl. Med., **6**: 528~530, 1965.