特別掲載

THE DETECTION OF HEPATIC TUMORS BY MEMORY-SCINTISCANNING

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メモリーシンチスキャニングによる肝腫瘍診断

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シンチグラムの診断能を向上させる方法として種々の対照度強調方式があるが，原理的には一度のスキャニングによつてすべての情報を含むシンチグラムを作製し，再生過程において種々操作を加えて分析読影する方法が最もすぐれていると思われる．著者はこの考えにもとづき，ブラウン管自体に記憶系を内蔵した特殊なオシロスコープ，中間調型メモリースコープをシンチグラム記録並びに再生装置として用いる方法を開発した．

画面の輝点と検出器とを連動させ，検出器よりの信号で一定輝度の輝点を画面に現わしてスキャニングを行えば，輝点の重り合いによつて計数率に応じて明るさの異つたシンチグラムがメモリースコープ画面上に描かれ，これは同時に蛍光面に接して置かれた記憶電極上に計数率に応じて強さの異つた正の電荷像として記憶される．この正に帯電した部分は読取銃から蛍光面全面に均等に送られる電子流を通過せしめて画面に像を現わすが，記憶電極の電位を下げてゆくと電荷の低い部分から次第に電子の通過が妨げられて蛍光面上から消えてゆき，僅かの電荷の差，即ち計数率の差を明瞭に知ることができる．シンチグラムは消去レベルを順次変えつつ観察し，適当な像をポラロイドカメラで撮影した後，電荷を中和して消去する．

この方法をメモリーシンチスキャニングと名づけ，基礎的実験と臨床面への応用を行なつて次の結果を得た．

1．メモリーシンチスキャニングでは，一回の測定で記憶させたシンチグラムを連続的に消去レベルを変えつつ観察できるため，計数率の差を迅速且つ容易に知ることができる．

2．^{131}I 600 μCi を含む深さ10cmの肝模型において，腫瘍相当の直径3cm，2cm，1.5cmのパラフィン球をそれぞれ深さ8.5cm，7.5cm，5cmまで検出しえた．

3．肝腫瘍症例では打点方式では見出し難い腫瘍をも明瞭に知ることができた．

Introduction

In 1954, Stirrett and Yuhl reported the first clinical application of hepatoscintiscanning.[15] Since that time, hepatoscintiscanning has been widely used as one of the most useful diagnostic aids for the detection of hepatic malignancies; and numerous modifications in scanning apparatus especially in recording device were elaborated with the purpose of obtaining more obvious delineation of the small lesion in the liver.

For interpretation of a scintigram, observation of serial scintigrams obtained in various cut off levels is often of great value.

The author has devised a new recording system of scintigram, in which display of serial scintigrams in various cut off levels could easily be performed with efficiency, and for this technique "the Memory-scintiscanning" has been adopted.

In the present paper, a method and results of the experimental and clinical applications of the Memory-scintiscanning are described.

Method

A block diagram of Memory-scintiscanner is shown in Fig. 1.

A conventional automatic scintillation scanner with a 2×2 in. thallium activated NaI crystal associated with 37 hole lead honey cone type collimator and a single channel pulse height analyzer were coupled with a memory scope using a half tone type memory tube, Hitachi Type V 108 (Fig. 2).

Fig. 1 Block diagram of the Memory-scintiscanner.

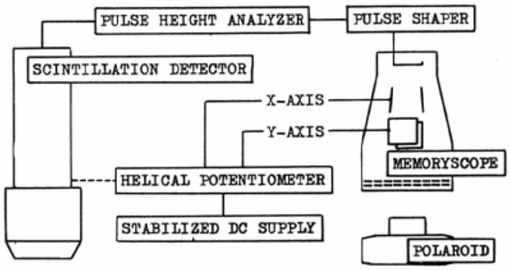


Fig. 2 Memory scope, Hitachi V-108.

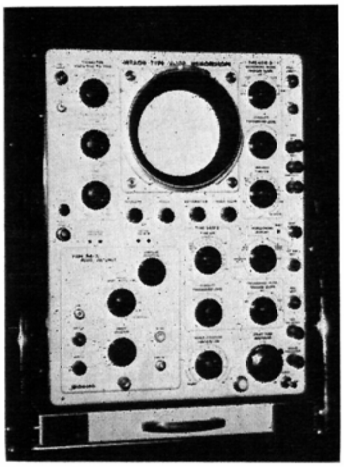
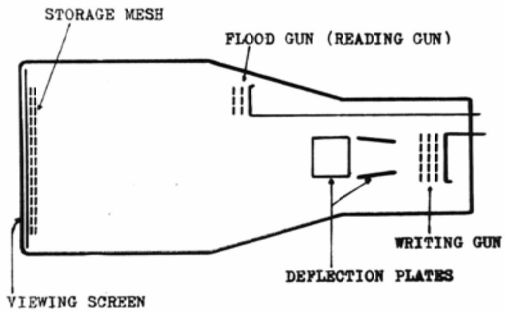


Fig. 3 Structure of memory tube.



Memory tube can store and dsiplay traces transiently observed on the viewing screen. The storage feature of memory scope is made possible through the use of a dielectric coated storage mesh and and two electron guns – a writing gun and a flood gun.

Fig. 3 illustrates a memory tube schematically. The dielectric surface of storage mesh is initially at zero potential (flood gun cathode potential) and does not permit the passage of flood electrons from the flood gun. The high velocity electron beam from the writing gun charges the dielectric surface positive as a result of secondary electron emission and consequently creates areas of partial transparency to low velocity flood electrons from the flood gun.

Electrons which pass through the positively charged areas are accelerated to high velocity, striking the viewing screen phosphor, thus producing a visible image of the pattern electrically stored on the storage mesh.

In half tone type memory tube, it is possible to register and display half tone information, and this feature of half tone type memory tube can be adapted for the recording device of scintigram.

In Memory scintiscanner, the synchronized movement of flying spot of memory scope with scintillation detector was accomplished by a system composed of a stabilized D.C. supply and multiturn helical potentiometers which were provided to produce D.C. signal levels fed to deflection plates of memory tube in proportion to detector's position.

Voltage of D.C. supply is voluntarily selected, so that any size of scan area can be recorded on the viewing screen of the memory tube.

The signal fed to the writing gun of the memory tube was amplified to 40 volts in amplitude and 4 msec. in duration. Scaling factor of two was employed provisionally for simultaneous recording of dot scintigram, but this was not essential in the Memory-scintiscanning.

Each spot of positive charge created on the storage mesh has uniform intensity and size, however, charge of various intensity is produced by overlapping of the spots in proportion to the counting rate. This gradation is recognized as difference in brightness on the viewing screen at the time of display.

Since the passage of flood electrons through the storage mesh is controled by voltage between the storage mesh and the flood gun, detailed investigation of difference in count rate is accomplished by changing the voltage of the storage mesh. As the voltage of the storage mesh is lowered, flood electrons are repelled from the less intensely charged area to the highly charged area and consequently gradational disappearance from low count rate range is observed.

Thus, the registered scintigram can be readily and rapidly interpreted. The scintigram is photographed in four to six various cut off levels using a Polaroid camera.

When interpretation and photographing are completed, electrically stored scintigram on the storage mesh can be erased in a moment by pushing the erase button. Memory scintigram can be voluntarily displayed on the viewing screen until about one week later unless it is erased.

Experiments

The following experiments were carried out with the purpose of establishing the usefulness of the memory scope as a recording device of scintigrams.

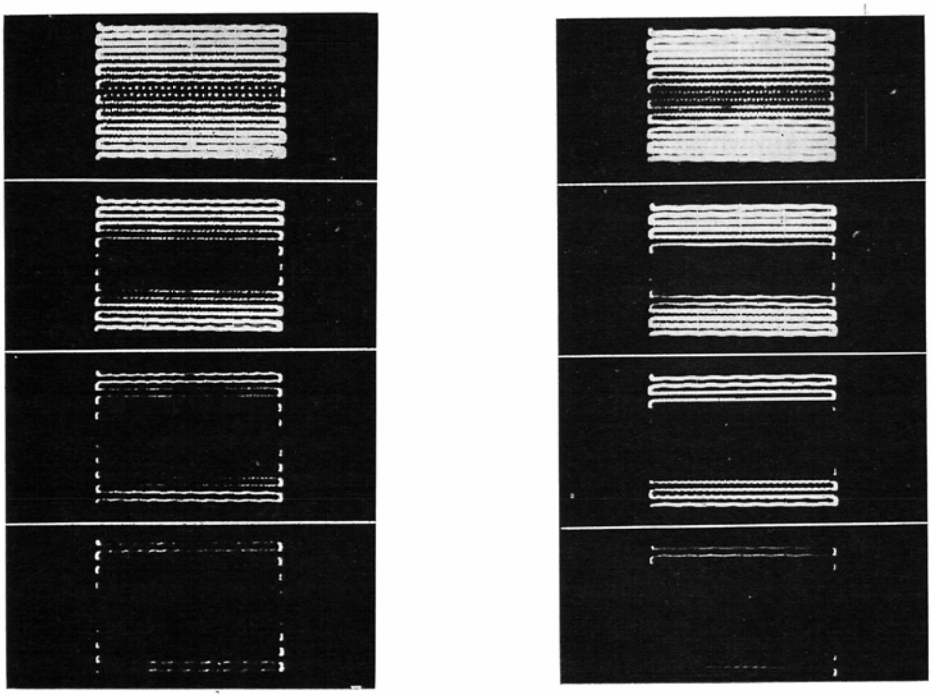
The first experiment using a pulse generator aimed to know whether the memory scope had an ability to display distinctly the small difference of count rate.

Signals of 10, 8, 6,4 or 2 pulses per second and 30, 20, 10, 6 or 3 pulses per second were fed to intensity modulation input of memory scope while scanning speed of the spot on the viewing screen was kept in 5 mm per second.

Registered patterns were observed in various erasing levels and photographed with the Polaroid camera. The results are shown in Fig. 4A and Fig. 4B.

Fig. 4 Test of memory tube using a pulse generator demonstrated an excellent delineation of difference in pulse frequencies. Pulse frequency was changed to 10, 8, 6, 4 or 2 pulses per second (A) and to 30, 20, 10, 6 or 3 pulses per second (B) in every two lines. The difference of pulse frequency was definitely shown by adjustment of erase levels. These serial patterns were obtained in a few seconds by simply turning the display control.

A B



Memory scope clearly demonstrated both of relatively small and large differences in the signal frequency by means of selecting the brightness of the viewing screen.

Prior to clinical application, an experimental scanning using a phantom was carried out to find out what improvement could be made by the Memory-scintiscanning.

A phantom, in cylindrical shape of 12 cm in diameter and 10 cm in depth, was filled with water containing about 600 μCi of radioiodine.

Paraffin spheres of 3 cm, 2 cm and 1.5 cm in diameter were placed in various depths of the phantom.

The scintiscanner was set at 364$\pm$25 KeV to accept the photopeak of radioiodine and to have a scanning speed of 8 mm per second.

Fig. 5A, Fig. 5B and Fig. 5C are the examples of memory scintigrams obtained on this phantom.

In memory scintigrams, paraffin spheres of 3 cm, 2 cm and 1.5 cm in diameter were obviously recognized to 8.5 cm, 7.5 cm and 5cm in depth respectively. These were not detected by dot scintiscanning in such depths.

Fig. 6 illustrates the result of comparative studies of the Memory-scintiscanning and dot scintiscanning concerning the relationship between depth and size of detectable paraffin spheres in the phantom. This comparison shows the fact that the superiority of the Memory-scintiscanning is more evident in detection of a smaller space occupying lesion situated in the depth.

Fig. 5 Experimental scans on a phantom bearing paraffin spheres of various sizes. The phantom is 10 cm in depth, 12 cm in diameter and contains 600 μCi of ^{131}I. (A) Sphere of 3 cm in diameter situated at 8.5 cm, (B) 2 cm in diameter situated at 7.5cm and (C) 1.5cm in diameter situated at 5cm below the surface of the phantom were obviously recognized by successive modifications of stored scintigrams.

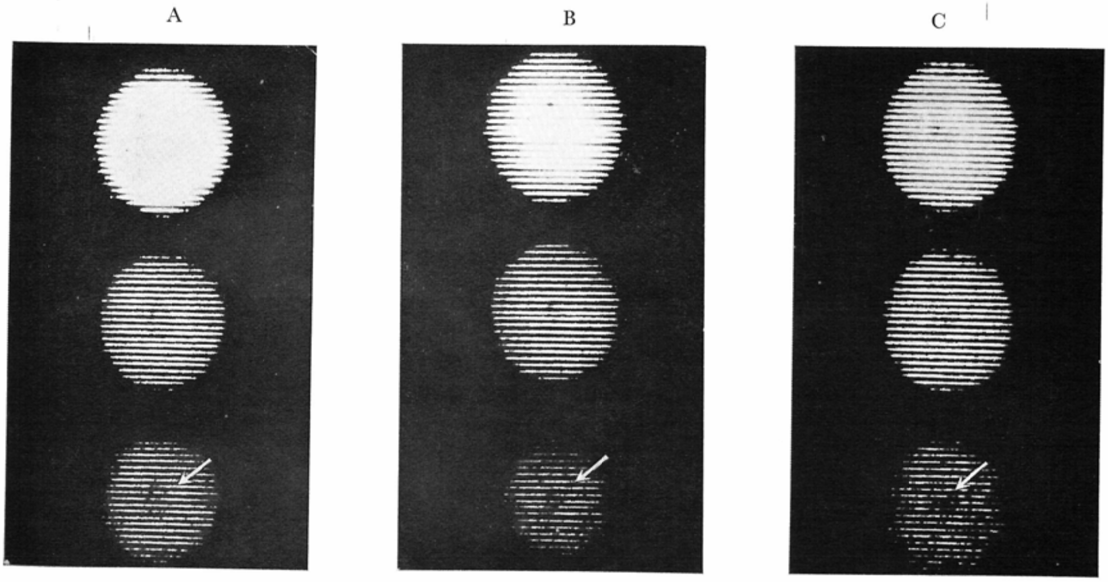
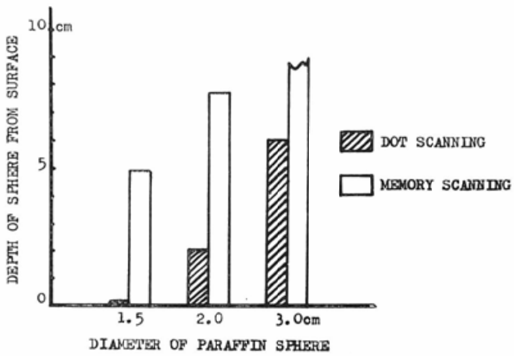


Fig. 6 Comparison of dot scintiscanning and the Memory-scintiscanning in respect of the relation between size and site of detectable paraffin spheres in the phantom.



Clinical results

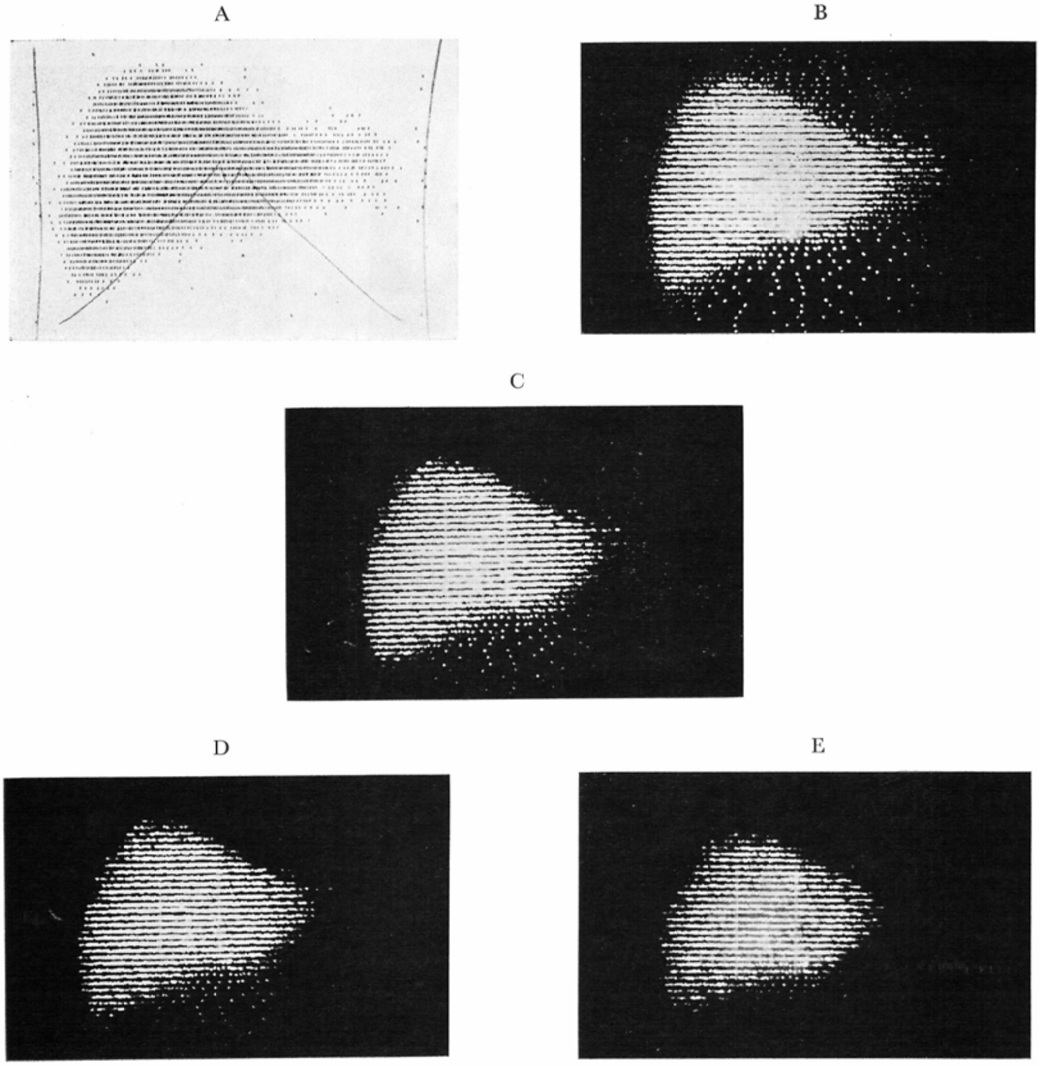
Among over 400 hepatoscans, 100 cases including 12 hepatomas, 29 metastatic tumors and 1 case of cyst were recorded by the Memory-scintiscanning.

Each patient had an intravenous administration of 8 μCi of colloidal radiogold per kg about 30 minutes before scanning.

Scanning speed of 8 mm per second and a 50 KeV spectrometric window centered on 412 KeV photopeak of radiogold were used.

Memory-scintigrams were interpreted and photographed selecting the most appropriate cut off

Fig. 7 A-E Normal hepatoscans showing simultaneously recorded (A) dot scintigram and (B-E) memory scintigrams with successive modifications of the erase level. As the erase level is increased, thinner portion of the liver is gradually eliminated but the distribution of radioactivity remains homogeneous.



levels for delineation of abnormalities.

Fig. 7 to Fig. 11 inclusive are typical clinical results selected to demonstrate the usefulness of the Memory-scintiscanning.

Fig. 7 is a normal hepatoscan showing a dot scintigram and series of memory scintigrams erased in four different cut off levels.

In the memory scintigram, periphery of the liver where the counting rate is relatively low gradationally disappears from viewing screen of the memory scope, as the cut off level is increased. There is no evidence of defect or irregularity in distribution of radioactivity.

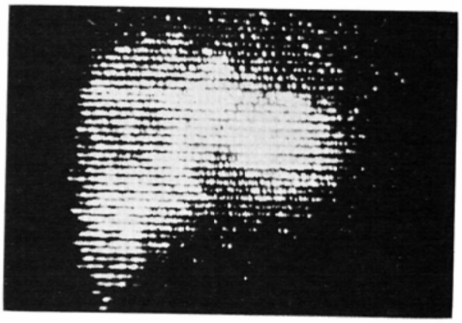
Fig. 8 and Fig. 9 are scans of the metastatic tumor of the liver. In these cases, space occupying lesions are much easily recognized in memory scintigrams by successive increase of erase level.

Scintigrams of the primary hepatic tumor are shown in Fig. 10 and Fig. 11. The former is a scan of hepatoma case and the latter is a scan of liver cyst. Dot scintigrams of both cases show resembling massive space occupying lesions, however, more detailed interpretation of scintigram allowed in the Memory-scaintiscanning reveals an evidence of more regular and sharp demarcation of lesion in the latter case. This is possibly an indicative finding of the benign tumor.

Fig. 8 A-E Hepatoscans showing multiple metastatic space occupying lesions. Multiple metastases (arrows) are more obviously seen in successively erased memory scintigrams (B-E) than simultaneously recorded dot scintigram (A).

A

B



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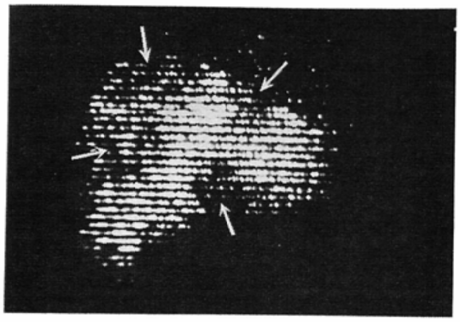

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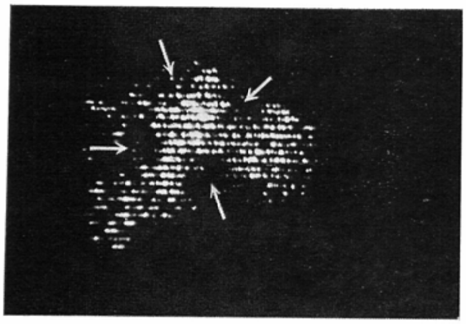

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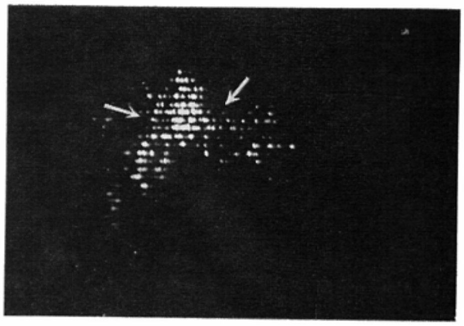
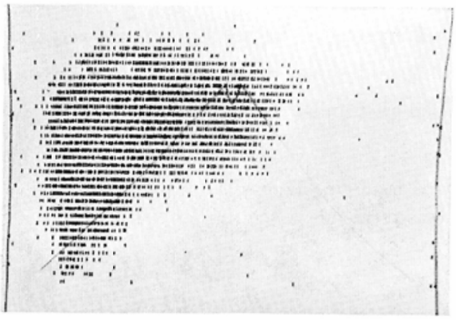


Fig. 9 A-E Liver scans showing metastatic space occupying lesions. In dot scintigram (A) areas of decreased activity are hardly visible. Properly erased memory scintigrams (B-E) show definite multiple space occupying lesions (arrows).

A



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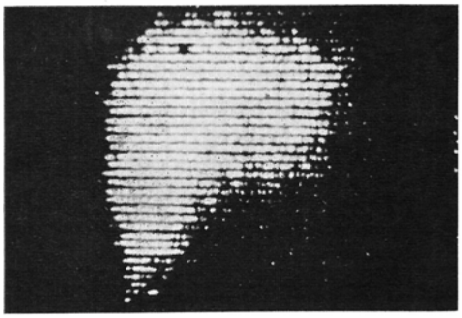

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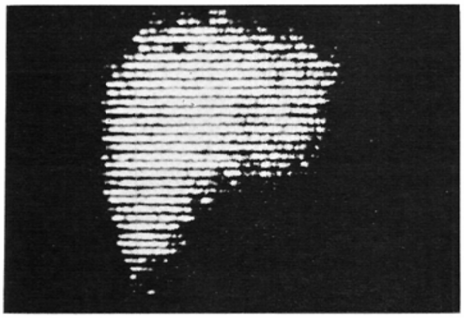

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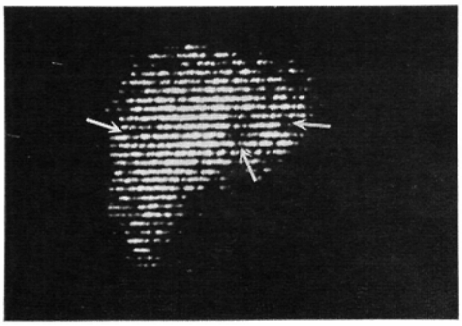

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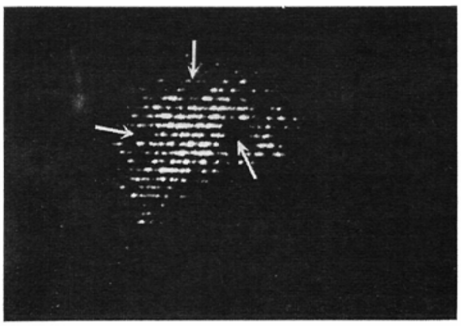
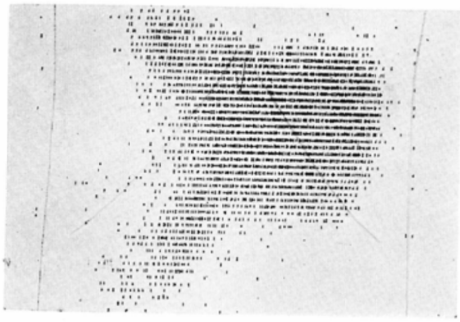


Fig. 10 A-F Hepatoscans demonstrating a massive defect of radioactivity in right lobe of the liver. (A) Dot scintigram, (B-E) Memory scintigrams and (F) autopsy specimen. Successively erased memory scintigrams show irregularity in demarcation of cold area (arrows) and some inhomogeneous distribution of radioactivity in left lobe. Autopsy revealed a histological diagnosis of hepatoma and several small metastases in left lobe.

A



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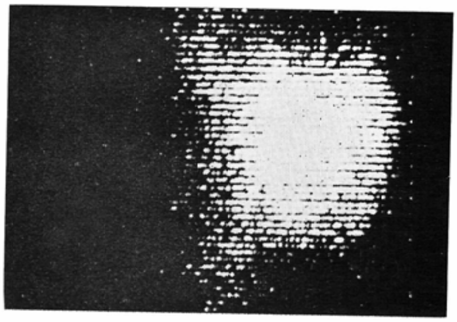

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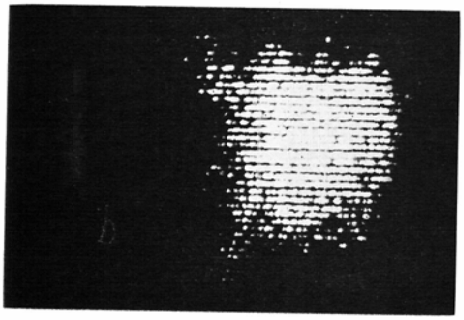

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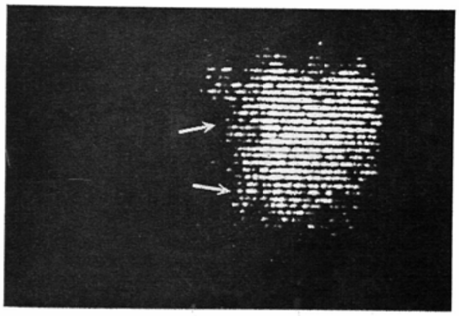

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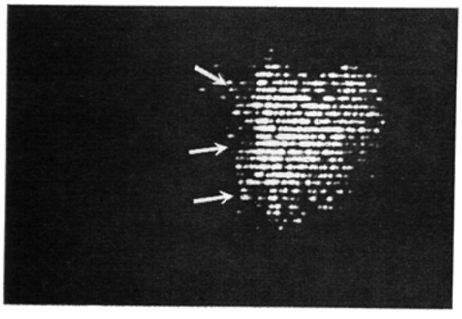
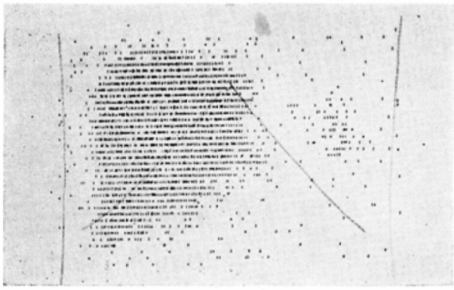


F

Fig. 11 A-E Hepatoscans showing a massive defect in left lobe of the liver. (A) Dot scintigram and (B-E) memory scintigrams. Memory scintigrams in various erase levels show regular and sharp demarcation of defect and homogeneous distribution of radioactivity in remaining right lobe. These findings suggested benignancy of the lesion. Resected specimen was cyst of the liver.

A



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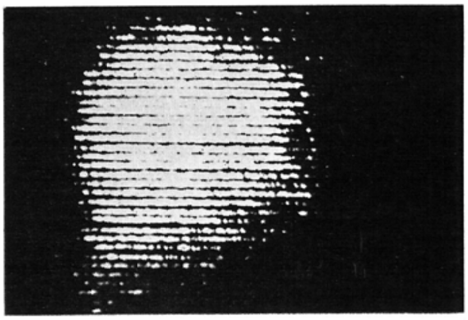

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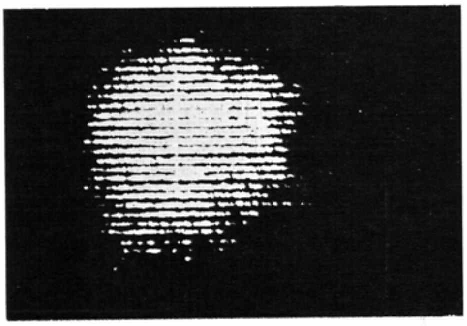

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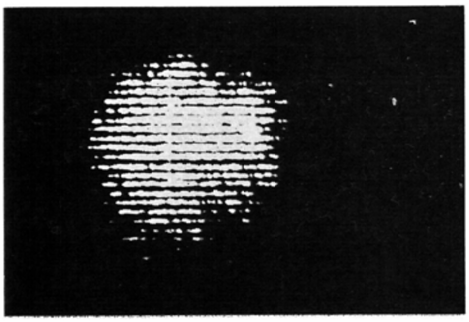

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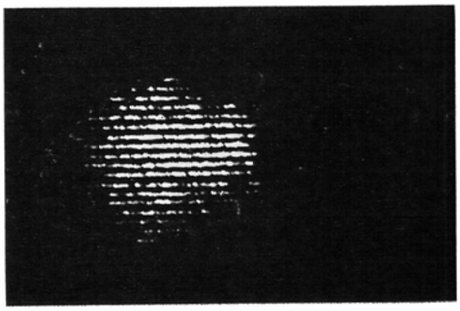

Discussion

Diagnostic procedure with the use of scintigram is based on recognition of the differences in count rates represented by distribution of dots in the dot scintigram, darkening of film in photo-scintigram or difference of color in color scintigram respectively.

Unfortunately, most of radioisotopes used for hepatoscintiscanning distribute in unaffected tissue, so that the detection of deeply situated small space occupying lesion is extremely difficult unless some contrast enhancement technique is employed.[1,5,6,7,9,10,11,12,13]

The major drawback of contrast enhancement techniques is a possibility to sacrifice the information which may be important for correct interpretation of a scintigram. Moreover, this sort of technique is often time consuming and laborious.

From this point of view, a technique by which all the informations received by the detector can be registered and later read out in appropriate cut off levels, is desirable; thus scan replaying systems using a magnetic tape recorder by Berne[3] and replaying technique using a closed circuit TV system by Bender[2], Charkes[4], Kakehi[8] and Rejali[14] were elaborated. Memory-scintiscanning has also been devised in the same principle.

The distinctive features of the Memory-scintiscanning are registration of all the scintigraphic informations as an original scintigram without suppressing the low count rate range and direct display of serial scintigrams on the viewing screen making voluntary selection of erasing ranges from zero to 100 per cent.

These features seemed particularly significant in the liver scanning in which the optimum level of background suppression is difficult to determine beforehand.

In the Memory-scintiscanning, detailed investigation of difference in count rate is possible even in thickest part of the liver where the detection of a small space occupying lesion is extremely difficult. In addition, the Memory-scintiscanning allows to visualize to the lowest count rate range such as faint uptake of radioisotope in the spleen or bone marrow which is occasionally significant for the diagnosis of hepatic cirrhosis and for differential diagnosis of primary and metastatic tumors.

Comparative study on detecting ability with other contrast enhancement techniques devised by many investigators would hardly be possible, because no standardized technique for comparison has been established, however, the present method of the Memory-scintiscanning has proved its diagnostic superiority over the conventional dot scintiscanning associated with background suppression circuit.

Another merit of the Memory-scintiscanning seemed to be readiness in displsy of the scintigrams in various erasing levels made under direct observation of viewing screen. Recall of scintigram in various cut off levels would be possible in a few seconds by simply turning the display control.

These surpassing features of the Memory-scintiscanning permit more extensive use of hepatoscintiscanning as a procedure routinely employed for the diagnosis of hepatic malignancies.

Summary

1) A newly devised recording system for radioisotope scanning by which all informations from the detector can be stored and later read out in various cut off levels is described.

2) In experimental scanning on a liver phantom measuring 10 cm in depth, paraffin spheres of 3 cm, 2 cm, 1.5 cm in diameter were detected to 8.5 cm, 7.5 cm, 5 cm below the surface repsectively.

3) Excellent results were obtained in delineation of space occupying lesion in clinical cases.

4) Readiness in recording and interpretation of the scintigrams in the Memory-scintiscanning permits more extensive use of hepatoscintiscanning as a routine procedure.

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