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Clinical Results with a Color-Recording Rescanner[1]

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Several methods have been devised to extract latent information in radioisotope scanning (1-13). Rescanning, which is one such method, was reported in 1962 by C. C. Harris and his co-workers (6). Methods for recording primary scans in color have been developed by several workers since 1959; they use the contrast effect of colors to allow visualization of small variations in counting rate (7-11). The idea of combining this color-recording method with the rescanning technique seemed to provide special usefulness and benefits for radioisotope scanning and a rescanner with photographic color readout has been designed (12). The first model was made in 1964, partly at the Oak Ridge National Laboratory (ORNL) and partly by the Technical Services Department of the Oak Ridge Institute of Nuclear Studies (ORINS). Preliminary results given here indicate the potential usefulness of this instrument.

METHOD

With an area scanner, high quality black and white photoscan records are obtained, which contain information about radioisotope concentration expressed as a degree of film density. This photoscan is then placed between the small light source and light sensor of the rescanner (12). The whole sensing and color-wheel system is contained in a small metal box that is moved about within a darkened enclosure (Fig. 1).

The color-wheel output was tentatively divided linearly and logarithmically into seven divisions. Color filters were selected and arranged so that light, warm colors corresponded to a high density in the original photoscan record, while dark, cold colors delineated the lower densities. White, yellow, orange, red, green, blue, and violet were used. Effects on the color record from rescan speed, spacing, light intensity and aperture size of the light sensor were analyzed.

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The black and white photoscans to be discussed were chosen from photoscans made on the ORNL research scanner at the ORINS Medical Division. This particular scanner was designed to record information over a wide dynamic range (6).

RESULTS

The major purpose of this rescanning instrument is the accentuation and visualization of small variations in counting rate that could only be suspected on the original scan record. The liver scan shown in Fig. 2 is from a patient scanned with ^{131}I rose bengal approximately one month before death. The liver at the time of this scan was enlarged with multiple cold spots throughout and a relatively large cold area between the right and left lobes. A liver biopsy and later autopsy revealed metastases from carcinoma of the lung. In an experiment using the rescanner, an attempt was made to see whether these cold areas could have been detected on any of this patient's earlier scans. The scan of Fig. 3 had been made four months earlier and was obtained two days after the administration of 2.5 millicuries of ^{198}Au for bone-marrow scanning. The patient at that time was admitted to the hospital having chronic anemia and chronic arteriosclerotic disease. The liver was palpable seven to eight finger breadths below the right costal margin and was moderately tender; the swelling was thought to be traceable to congestive heart failure. Little attention was paid to the slight abnormalities in liver concentration of this early scan (Fig. 3). The color-rescan (Fig. 4) made from the original record of Fig. 3, clearly demarcates areas of reduced concentra-

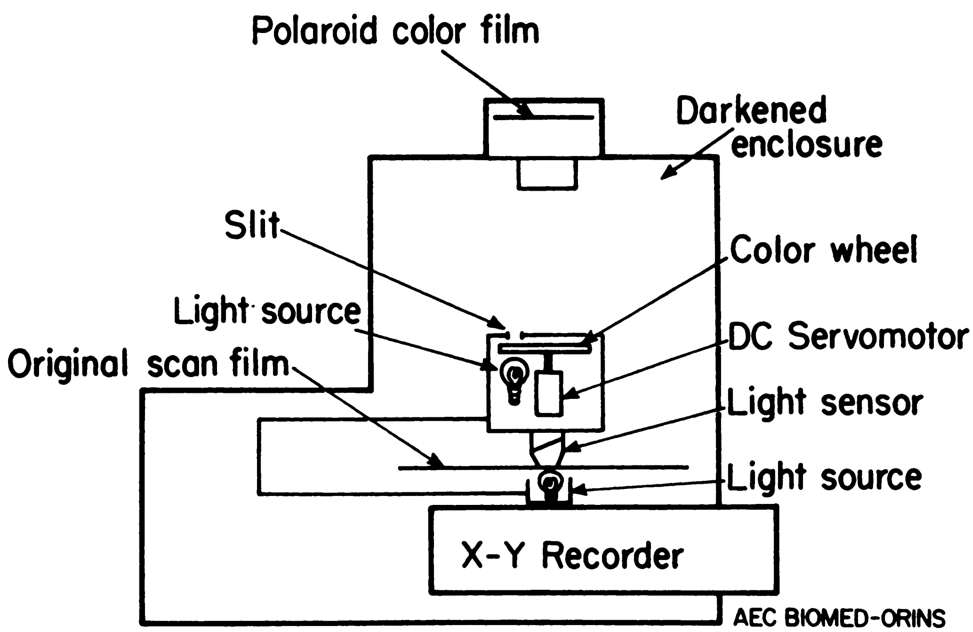

Fig. 1. Diagram of rescanner.

tion. We believe the reduced top-central activity, and also the abnormal color-band indentations appearing mainly in the lower portion of the left lobe, show early tumor growth, becoming more obvious later when the scan of Fig. 2 was made. In looking at the color rescan one might be tempted to dismiss the trend of reduced activity in the color record as a line of separation between the two liver lobes. Our experience with a large number of liver scans indicates that such a separation is not usually seen. This rescan was made with a color wheel having logarithmically arranged color filters.

Figure 5 is a rescan of the original lateral scan shown in Fig. 6 from a patient with a dermoid cyst in the posterior fossa. Four operations had been performed before this brain scan. Figure 7 is a posteroanterior view and Fig. 8 is the rescan. The original scans with 500 microcuries of ^{74}As (Figs. 6, 7) suggest some accumulation of radioisotope in the posterior fossa. Rescan results shown in Figs. 5 and 8 show more clearly the regrowth of tumor. A reverse-logarithmic sequence of color filters was used.

The rescanner can also be applied to the problem of analyzing original photoscans having very high or very low density patterns. Sometimes the only scan available is so dark that the detail of the radioisotope distribution is hardly interpretable. The rescanner helps restore the original details in those scans. Figure 9 (and also Fig. 12) is a rescan of the thyroid scan (Fig. 10) made soon after the patient was treated with 10 millicuries of ^{131}I for his large nontoxic goiter. The test dose scan was not suitable for analyzing the details of thyroid structure because of the overly dense record. Color rescan records made with different settings give us a better idea of the radioisotope distribution in the entire organ. The two color rescans (Figs. 9, 12) give different information on the black and white scan (Fig. 10).

In a low counting-rate scan such as is sometimes seen in a brain scan, in neck scans after thyroidectomy, or in a bone-marrow scan with poor concentration of the radioisotope (Fig. 11), statistical raggedness may make the interpretation difficult. The rescanner offers some assistance to this problem by smoothing the irregularity of the density in the pattern (Fig. 13). Such poor statistics are seen in the original scan (Fig. 11) that the rescan (Fig. 13) was done with the light probe setting a few tenths of an inch above the film.

DISCUSSION

The rescan patterns with colors give us quantitative information on density (opacity) of the original photoscan film. The relation between film opacity and output of the rescanner can be made fairly linear. But since the relation between counting rate and the density of the original scan film is not known, the colors in the rescan record do not directly correspond to the counting-rate range. An experiment using the ORNL photoscanner suggests that the form of the color versus counting-rate curve is sigmoid. The idea of the color filter arrangement in a logarithmic sequence for dark scans (such as a liver scan) and in a reverse-logarithmic sequence for light scans (brain scanning) is based on these data. A linearly livided color wheel is suitable for use with a scan of medium density range.

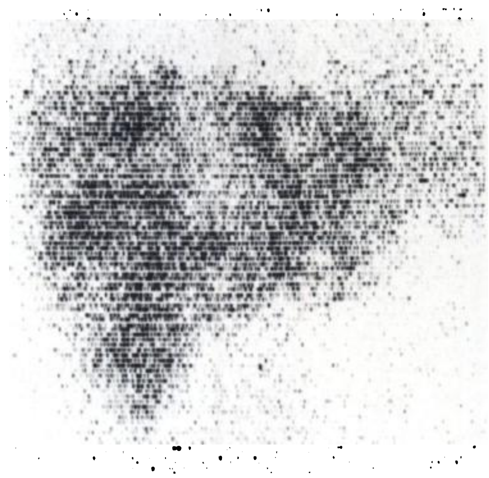

Fig. 2. Diseased liver scan.

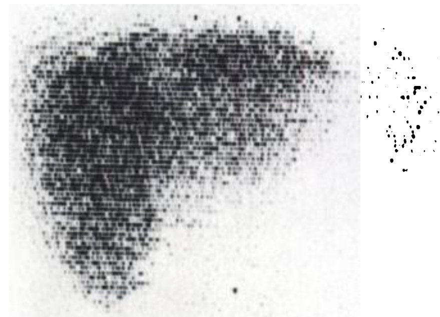

Fig. 3. Earlier scan of liver shown in Fig. 2.

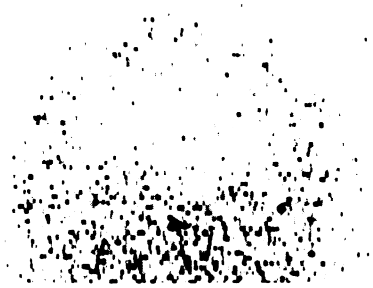

Fig. 6. Brain scan (lateral).

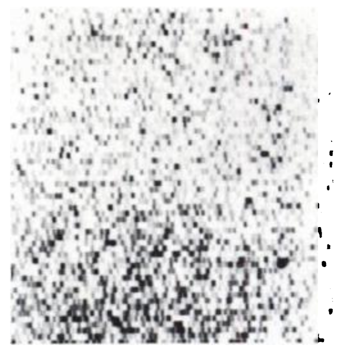

Fig. 7. Brain scan (posteroanterior).

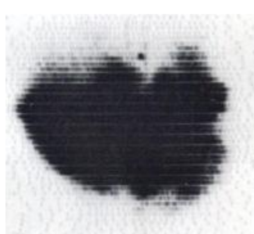

Fig. 10. Thyroid scan.

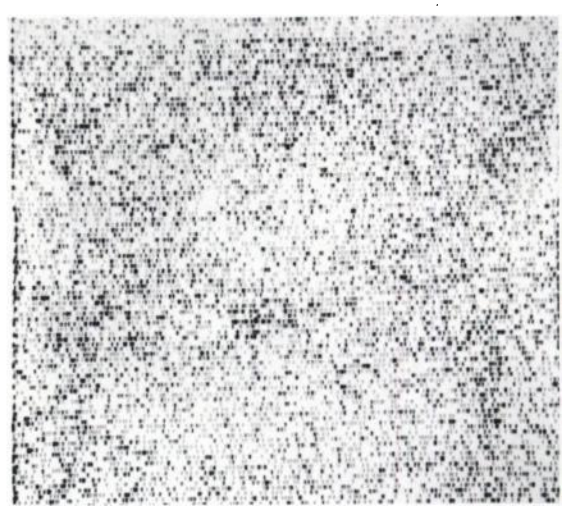

Fig. 11. Bone-marrow scan of pelvis.

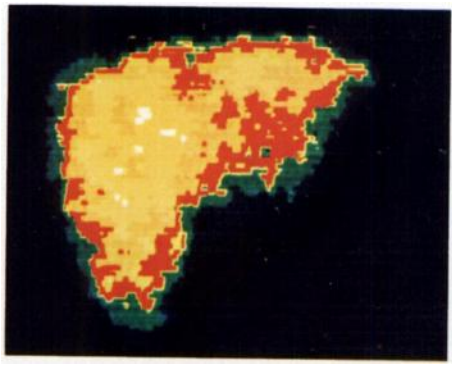

Fig. 4. Rescan of Fig. 3.

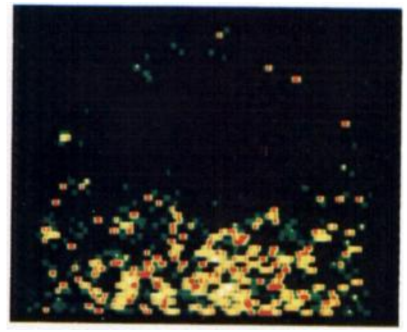

Fig. 5. Rescan of Fig. 6.

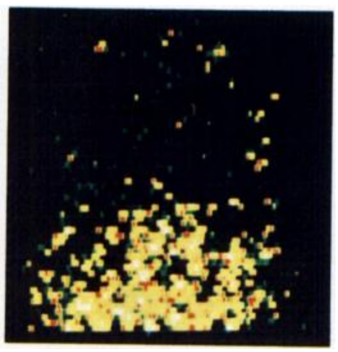

Fig. 8. Rescan of Fig. 7.

Fig. 9. First rescan of Fig. 10.

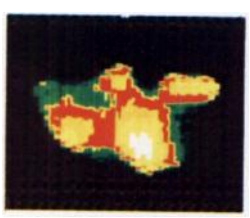

Fig. 12. Rescan of Fig. 10 at different settings from rescan in Fig. 9.

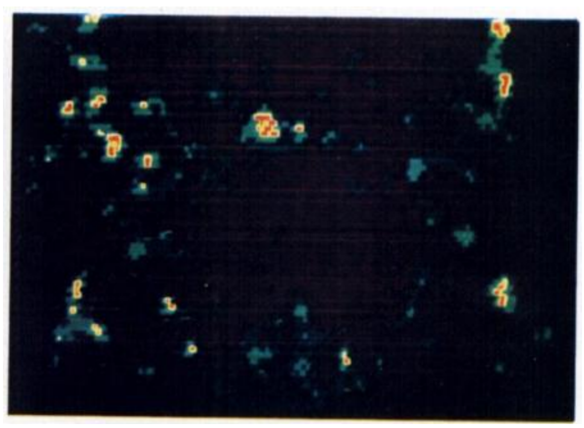

Fig. 13. Rescan of Fig. 11.

The optimum number of color filters is not yet known. In general, the more used, the more the details of density variations can be brought out, but too many colors in the record will reduce the interpretability because of exaggerated statistical raggedness by color contrast. Besides, as the sensitivity of the instrument is increased, the statistical deviation is also increased, as has already been pointed out by Christie and MacIntyre (13). Therefore, the optimum number of color filters must be decided by a compromise between the detectability of small variations and the smoothing effect of the colored areas on the statistical unevenness. The color wheel having seven colored filters tentatively used in this study was found to be fairly satisfactory. The relatively large aperture of the sensor also has a smoothing effect on the scan's statistical raggedness. The sensor sees an area of more than one line at a time, so that overlapping line areas are sensed with each rescan movement. The marks on the photoscan film fuse in the rescan record and a smoothed density map of colored components results: the larger the aperture the larger this fusion effect. On the other hand, this effect also reduces the discriminating ability for local differences in density. Therefore, the aperture must be chosen for each rescan according to the degree of unevenness in the original photoscan film.

Rescanning speeds of 0.5 and 1 in/sec are both satisfactory and 5 to 15 min is now required to make each rescanning record. Speeds of two and 4 in/sec were also tested, but they produced irregular patterns in the color records. This was because the response in angular displacement of the color wheel is too slow at these faster rescan speeds.

Direction of movement of the rescan head in relation to that used for the original scan appears unimportant if the original was properly made, but when bad line spacing is seen on the original film a cross-direction rescan is better.

From these preliminary results, some advantages and limitations were noted. The advantages are as follows:

1. Since the color recording method is not used in the original scan, the difficulties of attempting to make adjustments necessary to produce a perfect color scan while the patient is under the scanner are avoided.

2. Information stored in the photoscan record can be analyzed at any time without damaging the original record.

3. The color contrast in a rescan record shows small variations of counting rate better than a black and white scan does.

4. If desired, the statistical raggedness of the original record can be smoothed to a certain degree by rescanning.

5. Very dark or very faint original scans that are not suitable for interpretation with the naked eye can be refreshed.

6. Only a short time is required for each rescan because of the speed of the Polaroid color film and the servomotor mechanism.

7. The instrument is relatively simple to use and inexpensive to construct.

Most of the limitations in usefulness of this instrument are traceable to the quality of the original scan film. To produce a good rescan the original recording must be made over a wide dynamic range and the scaling factor should be as low as possible. Artifacts such as uneven line spacing in the original scan cause a poor rescan result.

The following disadvantages of this first model of the rescanner need further correction:

1) The angular displacement response of the color wheel is too slow for the higher rescaning speeds. By reducing the diameter and weight of the color wheel the response speed will be increased.

2) Trials are necessary to find the optimum settings for rapidly delineating an area of interest, with a different color, from the surrounding areas. If a higher rescan speed is available without distorting the image, these trials runs can be easily made and the proper settings can be found.

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