COLOR CODING COUNTING-RATE DATA ON EKTACOLOR PAPER—A NEW TECHNIQUE

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Many output systems, each with its advantages and limitations, have been developed for radioisotope scanning. The fundamental limitation of any scanning device is, of course, the detection characteristics of the probe combined with the ability of the electronic pulse-handling system to present the best signal-to-noise ratio at the output. All the information which reaches the output system should be used to produce the final image with minimum distortion imposed by the output system itself. Any system should have as its main objective the faithful presen-

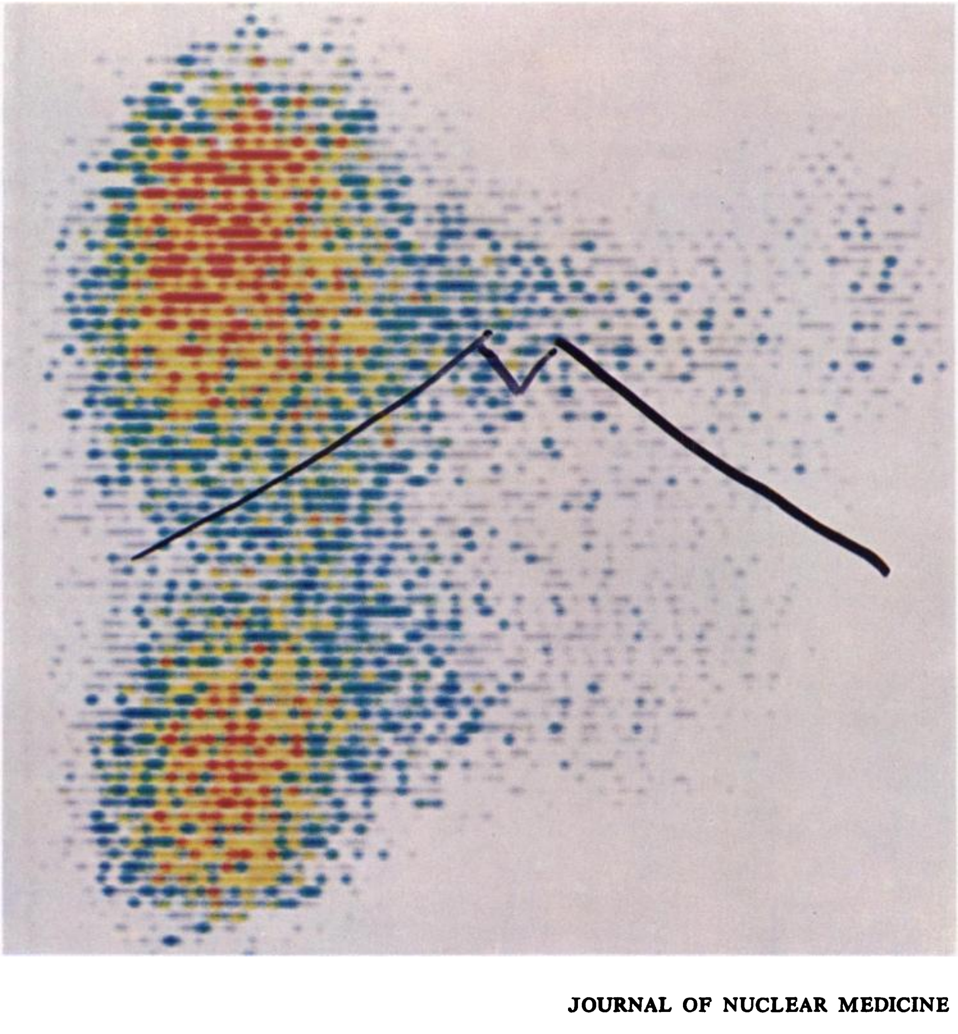

PLATE 1. Color liver scan showing areas of decreased uptake of ^{198}Au colloid. Patient has carcinoma of colon with metastasis to liver.

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tation of the counting-rate data as they are detected by the probe. Moreover, spatial changes in counting rate should be easily discernable by the human eye.

In the various types of dot recording, whether it is a solenoid-driven tapper or an electric arc marker, the area density of the dots indicates the relative counting rate. A black-and-white display of this type does not sharply separate areas of slightly different counting rate. Moreover, scalloping occurs because of the number of counts required to trigger the marking device (the accumulation or "dot" factor). Scan interpretation has been made easier by the introduction of a variety of colored dots (*1–4*) with each color representing a certain percentage range of the maximum counting rate encountered.

In the photoscanning process, dot frequency is not rate-meter-response dependent because light is flashed on the film for each pulse accepted by the pulse-height analyzer. The image produced on x-ray film by this method consists of spots of varying optical density. The optical density of the spots is not linearly related to counting rate, especially if contrast enhancement is used.

Kakehi *et al* (*5,6*) and Adams and Jaffe (*7*) have attempted to merge a film record with color-coded information. The method described below is a further effort in this direction and produces a life-size color-coded image of the counting-rate information on Ektacolor Professional Paper*. The device is inexpensive to manufacture, adaptable to most rectilinear scanners and electrically and mechanically simple. The image is available for viewing only 7 min after completion of the scan and costs about 90¢ per 11 × 14-in. print, including processing. We have added this device to a tube-type 3-in. Picker Magnascanner. The total cost of parts, materials and labor amounted to about $800. This includes the price of the semiautomatic color paper processor†.

DESCRIPTION

Information is obtained from the counting-rate meter, the output of which is d-c voltage proportional to the counting rate. This drives a single-stage amplifier with a balanced output and a multiturn potentiometer which allows a variable portion of the output signal to be selected. This signal drives a galvanometer movement (Fig. 1) selected so that the maximum output from the amplifier is sufficient to rotate the galvanometer to full-scale deflection. Because the output from the counting-rate meter is proportional at all times to the "instantaneous" counting

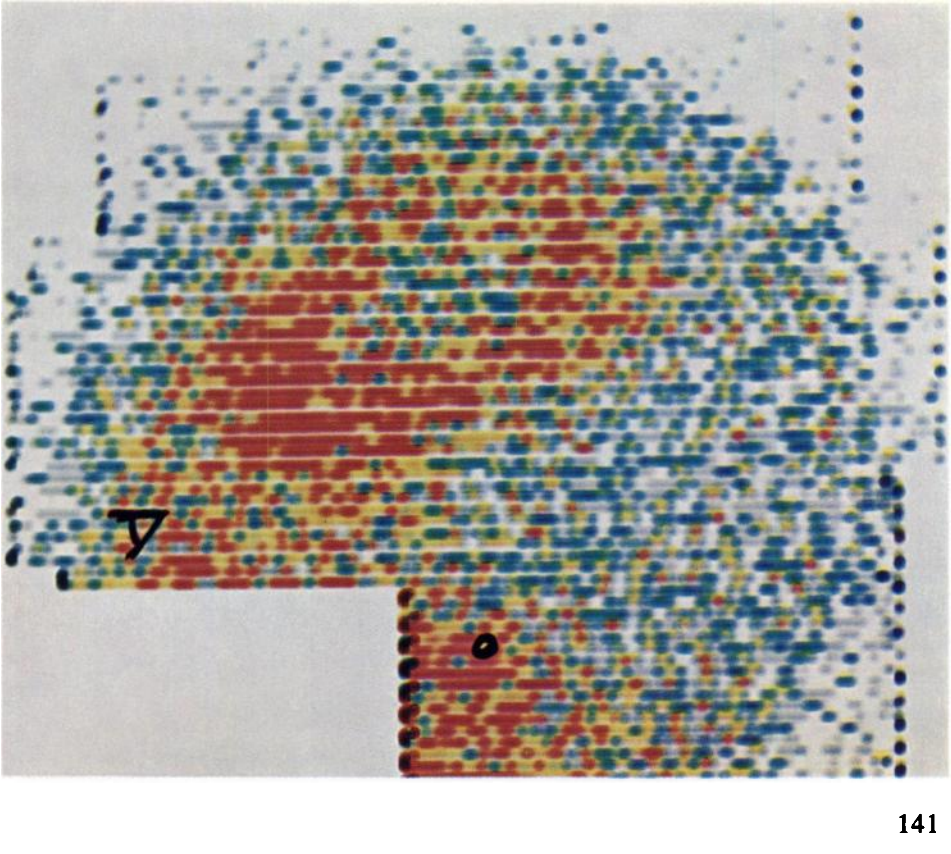

PLATE 2. Color brain scan made with ^{197}Hg-chlormerodrin showing massive temporal lobe infarct. Note that center of infarct contains less radioactivity.

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* Eastman-Kodak Co., Rochester, N.Y. Available in 8 × 10 in., 11 × 14 in. and other sizes.

† Eastman-Kodak Co., Rochester, N.Y. Rapid Color Processor Model II.

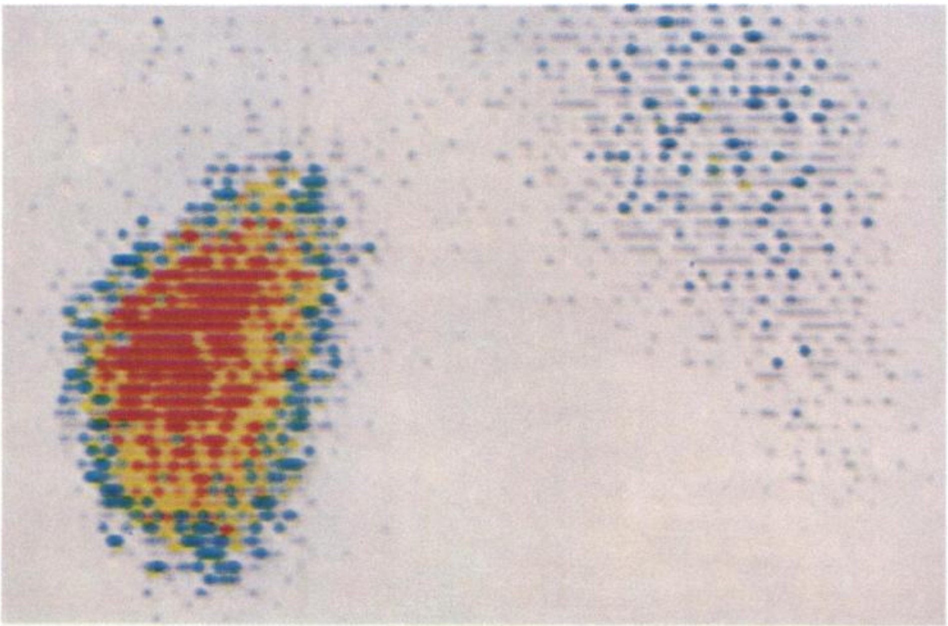

PLATE 3. Kidney scan made with ^{203}Hg-chlormerodrin showing absence of right kidney.

rate, the rotation of the galvanometer represents a counting-rate-dependent parameter.

Attached to the galvanometer shaft is an aluminum holder into which a piece of color negative can be inserted. A suitable color negative was obtained by photographing a fan-shaped array of eight color wedges arranged in a suitable order with Ektacolor Professional Film, type S. A spectral distribution was found to be the most satisfactory because most people associate cool colors with low counting rates and warm colors with high ("hot") counting rates. The color negative therefore displays the eight complementary colors of those desired in the final color print. The size of the color wedges was chosen so that each wedge represents 12.5% of the full-scale deflection.

Positioned directly above the color negative is a small tungsten lamp that burns continuously. A collimated light beam is directed downward through the color negative and through another collimator to form a sharp light spot several inches below. The galvanometer, color negative and light source are contained in a light-tight box which makes a rigid connection with the detector and therefore shares its movement during the scan.

Affixed below this unit and independent of it is a sheet of Ektacolor Professional Paper held in position by a Picker Nuclear film cassette. As the detector moves over the area being scanned, the "instantaneous" counting-rate information is conveyed to the galvanometer and transformed into a rotation of the galvanometer shaft. The amount of rotation determines which of the color wedges is directly in the light beam from the tungsten bulb. Therefore, a circular spot of light whose color is dependent on the instantaneous counting rate is recorded on the Ektacolor paper. To distribute the color scale correctly across the portion of the numerical counting-rate scale being used, the "hottest" area to be scanned is located manually before starting the scan and the output to the galvanometer is adjusted by the multiturn potentiometer to coincide with full-scale rotation of the galvanometer shaft. This procedure is indicated by the reading on a milliammeter connected in series in the galvanometer circuit. The sequence of colors from zero to maximum counting rate is white, grey, violet, blue, green, yellow, orange and red. A change from one color to an adjacent one represents a 12.5% change of maximum counting rate. Although all eight colors are

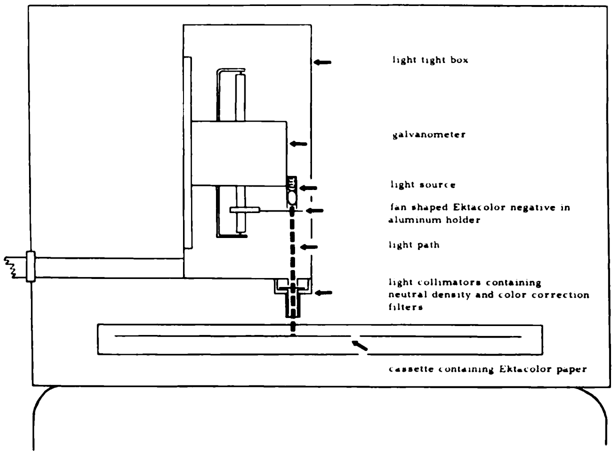

FIG. 1. Diagram of system used to make color scans.

easily seen in the scan, mixtures of those colors are seen when the counting rate is such that the galvanometer wavers between two adjacent colors. Consequently, the colors in the scan approximate a continuous spectrum rather than single discrete colors.

Appropriate color correction and neutral density filters are added into the light-beam path by placing suitable filters in easily changeable light-beam-shaper collimators to achieve the desired color balance on the Ektacolor print. Once this is done, only minor changes in color correction are necessary to compensate for variations in batches of Ektacolor paper. The change in color correction needed for each box of paper is indicated on the box label. The neutral density filters allow variations in the light-spot size and scanning speed to be used while maintaining the same final color saturation on the Ektacolor print. We use coaxial holders, the upper one containing the color correction filters. The lower holder fastens to the upper by a set screw and contains the final light aperture and the neutral density filters. We have a number of these holders available for each of two hole sizes, each holder containing a different neutral density filter. The holes are sizes that produce light spots of 2 and 5 mm in diameter on the Ektacolor paper and thus correspond to the light-spot sizes produced by the photorecorder. It is thus simple to empirically determine the correct filter for a particular light-spot size and scan speed. The small light spot is used with the 31-hole probe collimator and a spacing of 2 mm when high resolution is desired, such as when one scans the thyroid. The large light spot is used with the 19-hole probe collimator and a spacing of 5 mm when a higher counting rate is desired at the sacrifice of resolution.

The response time of the galvanometer is faster than the shortest time constant of the rate meter. Therefore smaller capacitors were inserted in the rate-meter circuit to provide time constants of $\frac{1}{16}$ and $\frac{1}{32}$ sec. The thyroid can be scanned with little or no scalloping at a speed of 25 cm/min and a maximum counting rate of as much as 100,000 counts/min.

CONSTRUCTION

A wiring diagram of the single-stage amplifier for tube-type Magnascanners is shown in Fig. 2*. Transistorized or newer tube-type Magnascanners have a recorder output jack on the back of the rate-meter chassis from which a portion of the signal can be used to drive the galvanometer. All of the amplifier components can be mounted on a chassis measuring 10 × 5 × 3 in. and mounted beneath the table.

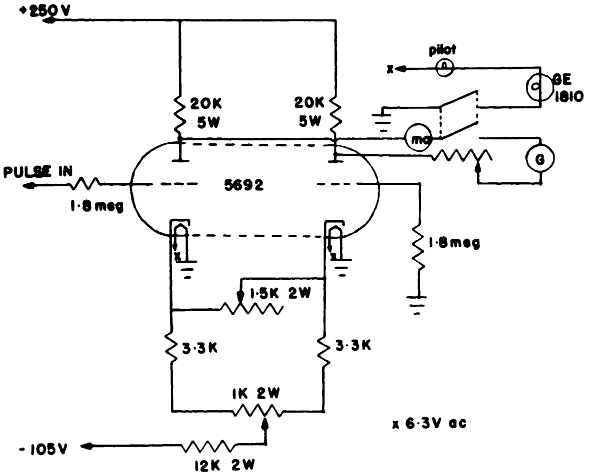

FIG. 2. Circuit diagram of single-stage amplifier for tube-type Magnascanner.

An outer light-tight box is made of 18-gage sheet of metal measuring 12 × 21 × 30 in. A ¾ × 16-in. slot is cut in the front to accommodate the film cassette. There are ¾ × 19-in. slots on either side for the support beam which passes through a light-tight movable shield to allow motion of the support beam in two directions while maintaining a light seal. The movable light seal consists of opaque vinyl plastic, the ends of which are attached to shortened window-blind rollers in the corners of the box. A sliding-type joint with a rim of felt is used so that the beam may pass back and forth as well as move longitudinally. The light-tight box is mounted on top of the Magnascanner, and the electrical connections to the inner box are made by a coiled four-conductor telephone cable.

The inner light-tight box, which measures 9 × 5 × 5 in. and is made of 18-gage sheet metal, contains the galvanometer. This inner box is mounted on a steel beam 2 × 37 × ⅜ in. which passes through the two side slots of the outer box and makes rigid connection with the beam which supports the probe by two inverted yokes measuring 14 × 4 in. (outside diameter). The inner box and the inside of the outer box are painted flat black to minimize light reflections.

Any rugged galvanometer with a short time constant can be used. We chose one from an Esterline Angus strip-chart recorder because it was available locally from a war surplus store for $8. The current requirements of the galvanometer coil should be determined so that a suitable multiturn potentiometer and milliammeter for the amplifier circuit can be selected. All excess weight is removed from the gal-

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* Compliments of Picker Nuclear, White Plains, New York.

vanometer suspension, and the stops are adjusted so that the coil is stopped just short of its full swing at either end. The color fan in its holder is attached by a clamp to the galvanometer shaft. The tungsten bulb and collimator are attached to the galvanometer magnet, and the color fan is placed so that the light beam passes through the midpoint of the red and opaque filters at the full-scale and zero positions of the galvanometer movement, respectively. The beam shapers containing the color correction, and the neutral density filters are mounted on the bottom of the box below an exit aperture.

The light source is a GE #1810 tungsten filament, 6.3-volt bulb that draws current from the filament circuit of the rate meter. The light-shaper collimators, which are painted flat black, are machined from brass, and the light-spot sizes are 2 mm and 5 mm in diameter, respectively.

OPERATION

To operate the system, one carries out the following steps:

1. Place the Ektacolor paper in the film cassette. The 14 × 17-in. Picker Nuclear cassettes will accept the 11 × 14-in. Ektacolor paper in either a lengthwise or crosswise position. In comparison to the photorecorder, the cassette containing Ektacolor paper is inserted upside down. The back of the cassette holds the paper firmly against a ¼-in. lip on both sides and front of the cassette if the paper is inserted crosswise and on the front and one side if inserted lengthwise. We have not experienced any difficulty with the paper becoming detached from the cassette.
2. On finding the area of highest counting rate, adjust the multiturn potentiometer so that the milliammeter indicates the full deflection of the galvanometer.
3. Remove the dark slide and begin the scan.
4. On completing the scan, process the Ektacolor Professional Paper by the Kodak Process System using the Kodak No. 11 Rapid Processor. A darkroom with a sink and water supply whose temperature can be adjusted to 100°F is required. The first 3.5 min of processing is done in the light from a No. 10 Safelight. The remaining 3.5 min of processing can be done in room light.

Processing Ektacolor Professional Paper by the Rapid Process system is easy and simple. A technician who is unfamiliar with photographic techniques can be trained to produce consistent-quality prints in a short time. There are five chemicals and ten steps in the processing of Ektacolor Professional Paper. Temperature control is critical only for the first step, which is 2.5 min of development at 100°F. Complete processing instructions accompany each box of Ektacolor Professional Paper and CP-5 Processing Chemical Kits.

The color print can be viewed immediately although the colors become more brilliant when the print has dried. The print dries with a durable glossy finish, and the colors are very fade-resistant although exposure to direct sunlight or ultraviolet light for long periods will result in some loss of color saturation. The addition of 5–10% Kodak Print Flattener solution to the final preservative solution prevents print curling and cracking in dry weather.

Plates 1, 2, and 3 are representative scans obtained with this system.

CONCLUSIONS

It is our feeling that scan data coded in this manner represents the best type of readout system yet available for visual evaluation. While this may be of little importance to the individual who is skilled in evaluating color dot scans or photoscans, it is clearly of value when discussing scans with persons not so familiar with nuclear medicine. In the occasional case, we feel that it has been possible to derive more information from the color scan, even by an experienced viewer, than from the photoscan.

In addition to its simplicity, such a system of color coding embodies the best qualities of the color dot-scan system and photoscan. It avoids the need for the accumulation or dot factor. Instead, it provides a one-for-one life-size recording mode with the improvement in visual counting-rate differentiation provided by the method of color coding.

ACKNOWLEDGMENT

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