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Digital Processing/Display System for Radioisotope Scanning[1,2]

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INTRODUCTION

Clinical radioisotope scanning entails the *in vivo* detection, recording, and comparison of radionuclide concentrations within organs and the surrounding areas. Details of many specific scan recording techniques and procedures have been reviewed comprehensively elsewhere (1-8). Generally two methods are now used to record scanning data. One of these, where a special purpose or interpretative result is desired, employs analog principles. Examples of analog records are strip chart recordings of count rate for two-dimensional (9) or three-dimensional plots (10), and "photorecording" (11-13). The second method for recording scanning data relies on digital means, utilizing output devices such as the dot tapper (14), teledeltos (15), and more recently, the "high speed" dot tapper (8, 16), or photographic digital recording (17-20). Combinations of the analog and digital methods also are used in order to secure certain advantages of both methods. These systems may exploit count-rate modulation of contrast, a digital photorecording device, or experimental combinations such as the photomultidotter (8) and the half-tone matrix printer (21). A recently developed hybrid system that has promise employs selective count range colors for print-out (8-22).

As a whole, much of the equipment and many techniques now used for radioisotope scanning do not produce good results often enough. In the belief that the use of advanced methods of digital data collection, storage, and processing procedures will help to solve some of the outstanding problems encountered, an automated radioisotope scanning system that incorporates many digital principles and methods has been developed. This system expresses the values of counts accumulated for fixed time periods in digital form, relates them to position, stores the data in the programmed scanning sequence, and transmits the scan information by dataphone to a remotely located computer center for

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[2]Supported by the Veterans Administration.

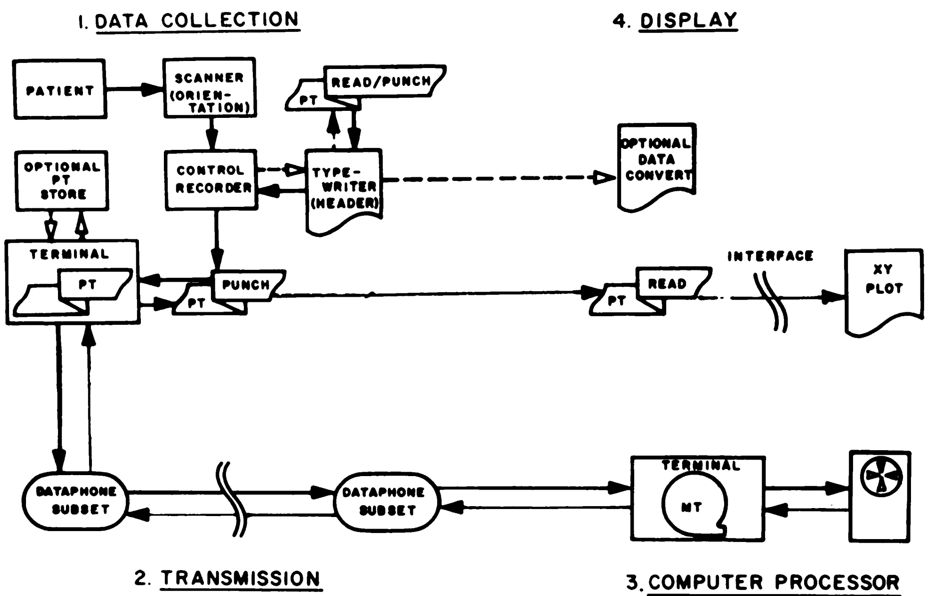

Fig. 1. Block diagram, Scan display system.

processing. The final computer processing function is designed to permit automatic preparation of the final display in contour map form. The inclusion of telephone transmission, high speed telecommunication procedures, and automatic computer processing increases the capacity and flexibility of the system, and provides a basis for a data acquisition complex that could serve several laboratories and provide readily available computer analysis for a diversity of biomedical data.

SCANNER SYSTEM AND PROCEDURES

The system configuration consists of four functional sections. They are: (1) Data Collection, (2) Transmission System, (3) Computer Processor, and (4)

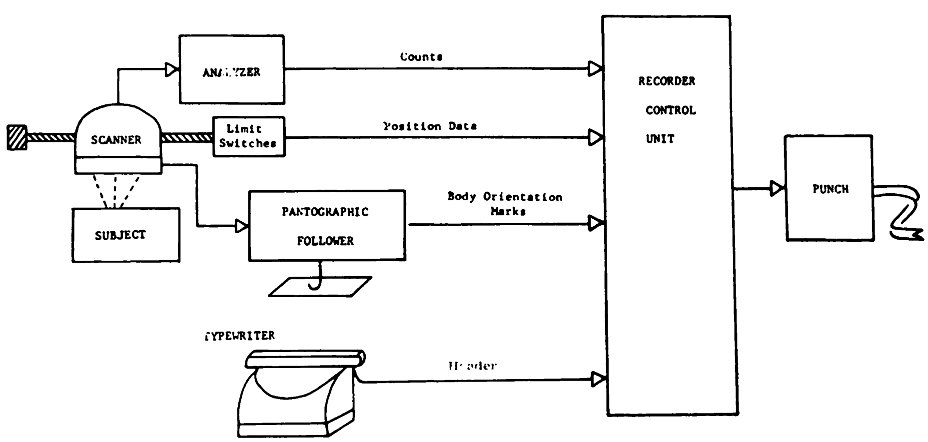

Fig. 2. The Data Collection Station produces a punched paper tape record.

Display Plotter Device. Their interrelationships are shown in the flow chart of Figure 1.

(1) *Data Collection.* The data collection system, shown diagrammatically in Figure 2, consists of a commercial radioisotope scanner,[1] pulse height analyzer, and the Control Recorder Unit.[2] Together, during a scan these elements relate the physical position of the scanner to time units. This is made possible when the control recorder unit receives the count signals from the analyzer within fixed time intervals. The time intervals are manually preset by means of a front panel variable control on the Control Recorder Unit. This control establishes the collection interval that the signals are accumulated in the electronic counter. These basic counting intervals are generated by an electronic clock, and range downward on a binary scale from four seconds to a minimum interval of 1/16 second. Greater collection speed is unnecessary because collimator resolution and count density are limited. Theoretically, the shortest time interval available permits accumulation of counts from a minimum length of about 0.02 inch of sweep, with a maximum scanning speed, for this scanner, of 12 in/min. Even this time interval-scan speed relationship should not introduce any distortion beyond the appreciable inaccuracies related to the collimator structure itself. The two features of minimun "resolution" distances and the wide selection of clock intervals available will permit use of low count densities, decrease scanning times, and allow for improvement of crystal-collimator arrays.

During a scan high speed impulses from the electronic clock transfer the accumulated counts from the electronic counter storage to a paper tape punch register, and reset the counter to zero. The accumulated totals for one scan segment are then punched as three digits on one-inch, eight-bit perforator tape. Meanwhile more count data are accumulated.

In order to conform to the count densities that are most likely to be encountered in scanning procedures, and also to cover a wide range of counts, the electronic counter is designed to record the digits over a range from 000 to a maximum count of 999 for *any* time interval selected. Each count, represented by three characters (chars) is followed by an end-of-count char to form a "word". To increase the recorded count density from a low to a higher value the basic timing sequence can be increased up to the four second count collection interval, and the scan speed may be decreased. A more significant restriction on the maximum rate that any data can be recorded is the minimum selectable time interval governing the frequency with which each data input word can be transferred to the paper tape punch and recorded. Obviously, the maximum rate at which the punch can record each four-char word must be greater than the data input rate in order to prevent discrepancies and recording errors. Because the highest speed of the tape punch is 100 eight-bit chars/sec, a single word can be punched within every 0.04 second. With this speed it is clear that the tape punch capacity cannot be exceeded even at the minimum clock interval setting of about 0.06 (1/16) second.

[1]Nuclear-Chicago Corporation.

[2]Digitronics, Inc., Long Island, N.Y.

In addition, the count sampling capacity of the system is comparatively high. Specifically, the maximum count "rate" that the system is able to record is the product of the maximum word value of 999 multiplied by the number of count data words collected each second. At the minimum count interval setting of 1/16 second the number of words collected is 16/sec. Thus the maximum rate is 999 × 16, or 15,984 counts/sec. In theory, this rate of recording capacity is equivalent to the disintegration rate of about 0.4 μC of radioisotope, but if the usual counting efficiency characteristics of the equipment is taken into consideration, then the count rate input capacity of the Control Recorder Unit-punch combination is equivalent to the count rate from about 4 μC of radioisotope, measured at the face of the scintillation detector crystal. If a count rate that exceeds 15,984 counts/sec at the minimum time setting (or a count rate that exceeds a value of 999/word at any other time setting) is presented to the Control Recorder Unit to be recorded, a built-in audio-visual "overflow" alarm is activated. In practical use, "overflow" conditions have been produced only when count rates from prepared radioisotope phantoms have been measured at the four second maximum clock interval. By switching to the next shorter interval of *two* seconds the individual word count values from the phantoms can be decreased to 999 or less. In view of the factor of 64 that the entire range of time settings from 4 seconds down to 1/16 second affords, the fact that a single change from the maximum to the next lower two second interval collection time interval is sufficient to bring a rather high count rate into the range of the count measurement capacity of the system, indicates that the probable maximum system capacity is more than 30 times as great as that required for phantoms used so far. Experience suggests that in biological studies at the count levels found in tissues the upper count limit capacities will not be so closely approached. On the contrary, it is necessary to use the longer count collection time intervals in order to increase the apparent count densities recorded, and when these are very low, to consider the use of specialized computer programming procedures to emphasize small statistical differences.

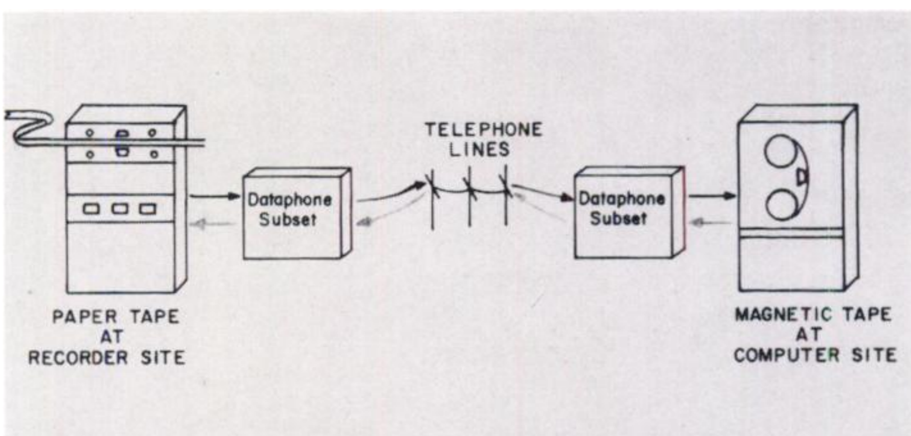

Fig. 3. In the bi-directional Transmission System the paper tape Dial-O-Verter transmits the data to and from the computer site where it is received on magnetic tape.

The amount of tape punched to record a sequence of scan words is related to the operational speed of the scanner, the count time interval, the word length, and to the fixed spacing of the chars punched in the tape (10/in). As an extreme example, punching tape at the maximum recording speed of 16 words/sec, at a scan speed of 0.2 in/sec, will produce 32 in of tape/linear in of scan. This calculation is expressed as:

$$\frac{(16 \text{ words/sec})\ (4 \text{ char/word})}{(0.2 \text{ in. scan/sec})\ (10 \text{ char/in. tape})} = 32 \text{ in. tape/in. scan}$$

At these settings, a 20-minute scan would require 640 feet of tape: usually the count densities are not high enough to justify as fine a resolution of data as these settings represent. However, these time settings and scan speeds were selected to furnish a maximum figure for tape requirements. In actual practice many 20-minute scans require a total of about 20 feet of tape.

While scanning, the Control Recorder Unit also generates a special char to represent the initiation of a transverse sweep. At the start of the first scan sweep, an impulse causes one of these chars, "start-sweep-left" or "start-sweep-right," to be punched. Following this, the count words detected over each sequential portion of the traverse are recorded automatically under control of the electronic clock. At the end of the initial sweep when the detector reverses direction, the second, but different start-sweep char is inserted into the tape record. The first start-sweep char is re-inserted at the end of the return sweep, so that only one of each of these two start chars characterizes opposite ends of the sweeps. In this way the start-sweep chars define the limits of the scan borders as they are punched on tape. The Control Recorder Unit is so constructed that it does not immediately punch out any count detected at the very edge of the scan border while the collimator head indexes and the end-of-sweep char is being recorded. However, a count in this area is not "lost" because of this Recorder characteristic, even though it is very likely that it represents background radiation and occurs very infrequently. Instead, during the moment of sweep direction change the occasional count in this area is transferred from the scaler, and accumulated by the Recorder Unit, and then is added to the initial word of the new sweep. The accuracy of this procedure has been borne out repeatedly, not only by the consistent uniformity between the number of words produced in consecutive sweeps, but equally as well by the values recorded in the initial word of each sweep. Even if a single count were to go undetected by some recording malfunction, or was read onto the tape record within the word count that represents perhaps the first 5 mm of the sweep, it would lack statistical significance. Also, it would be very difficult to assign *clinical* significance to the gain or loss of a count at the extreme border of a scan, where, in the absence of any concentration pattern, counts usually occur so randomly. A phenomenon observed much more frequently at the beginning of a sweep is the insertion into the tape record of two immediately consecutive start-sweep chars, instead of the single one required. This is caused by transient voltages produced by the d.c. motors when the sweep direction is reversed. To avoid any error from this source the computer program discards any sweep chars not separated from another one by data words.

A special "block" symbol that has specific functions in the tape record transmission procedures is also punched at the beginning and end of every scan, so that each scan data record will be preceded by its separate identifying data or header. Before the scan itself is recorded the header is introduced into the scan tape from a tape produced on a manually operated keyboard,[1] indicated in Figure 2, the keyboard assembly reads and punches the header record into the scan tape through a "type" operation mode built into the Recorder Unit. The only programmed limitation on the identification header is that it must contain at least 15 chars.

Besides header information and count data, a third system input is body orientation marks that indicate the relative position of the area to be scanned. A pantographic follower, indicated in Figure 2, with a special contact electrode attached to the scanning head, permits recording of these data. The electrode rides over paper, pierced at points selected to correspond to anatomical landmarks. During a scan when the electrode makes contact through these holes with

[1]Friden "Flexowriter", Model SPS.

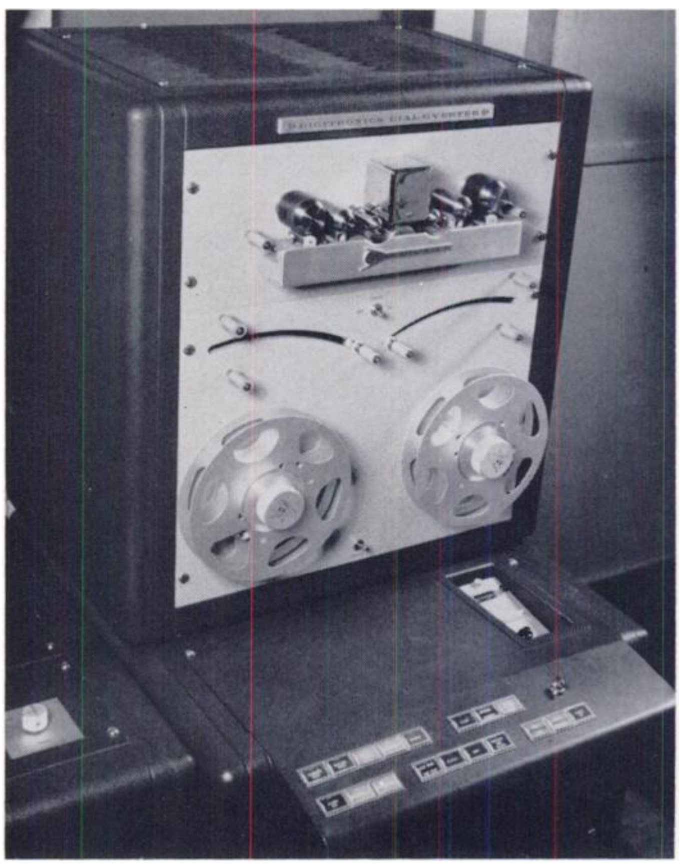

Fig. 4. Paper Tape Dial-O-Verter at Data Collection Station.

a conductive plate a pulse is generated. For each contact made this pulse automatically causes a predetermined char to be inserted into the paper tape record. Since codes can be punched in the tape within 0.01 second, body orientation marks are inserted without interference with the word count recording. The procedure followed to the present makes provision for three orientation points. It is possible for the electrode to miss one of these points during a scan and record only two of them. Even so, the two points recorded plus the line segment between them will still locate the planar position of the area scanned.

2) *Transmission System.* A diagramatic representation of the transmission functions is shown in Figure 3. The data are transmitted to and from the computer site over a commercial dial system telephone circuit via Dataphone subsets, Model 202A. A type 4A circuit, or equivalent, is the basic facility within the telephone transmission configuration, and is used to meet data quality specifications per U.S./VF land line tariffs. The envelope delay is stated as 1000 μsec at 1000-2400 cps. The amplitude vs frequency, measured with reference to loss at 1000 cps, should be -1 to $+3$ db at 1000-2400 cps, and -2 to $+6$ db at 300-2700 cps. The information punched on paper tape is transmitted from the Data

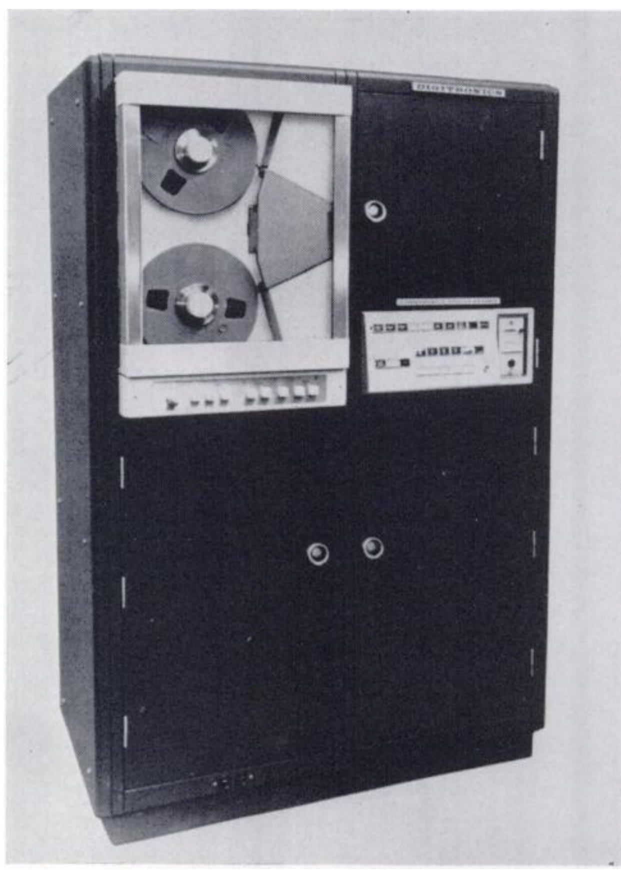

Fig. 5. Magnetic Tape Dial-O-Verter at Computer Site.

Collection Station to the computer site by means of a modified Paper Tape Unit,[1] Figure 4, at a rate of 150 char/sec. At the computer site the data are received by a buffered Magnetic Tape Unit,[2] Figure 5, and converted to BCD format. This unit writes it directly onto magnetic tape so that it is compatible with the computer input. Some examples of the code conversions are shown in Table I. At the transmission rate stated a 20-minute scan would be transmitted within 20 seconds, but nearly 30 seconds are required because of the automatic error checking and block repeating features that are built into the transmission units.

3) *Computer Processor.* At the computer site an IBM 7094, with a 32,000 word internal storage capacity, processes the data. This computer is used because of its accessibility, speed, and versatility, but other computers could be utilized similarly in different operational situations. A program prepared for the computer processes and sequences the digitized scan data and inserts special codes where needed. The program codifies the data in final form with special instructions to drive the display plotter unit. The master computer program to carry out these steps is now almost completely "debugged". In final form it will consist of five subprograms. A block diagram of the stored computer program which will generate the output data is shown in Figure 6. The magnetic tape output of the computer (about 20 per cent less than the input data) is re-transmitted by the Magnetic Tape Unit back to the Data Collection Station, where it is recorded on paper tape. Although the Magnetic Tape Unit can transmit at the same speed as the Paper Tape Unit (150 char/sec), transmissions are restricted to 100 char/sec to conform to the top receiving speed of the paper tape punch.

4) *Display Plotter Device.* The computer-processed data are received onto punched paper tape at the Data Collection Station location. Then the paper tape reel is transferred to a tape handler-reader to the input that is coupled by way

[1]Digitronics Dial-O-Verter, Model D505.
[2]Digitronics Dial-O-Verter, Model D520.

TABLE I

SYMBOL BIT STRUCTURE

Symbol	*Bit Structure* Paper Tape[a]	Magnetic Tape[b]
End of word	8	48BC
Start sweep (left/right)	156	1A
Start sweep (right/left)	12456	128A
Stop read	124	48
Orientation	12457	48AC
Error	567	AB

[a]For 8-channel, 1" paper tape, with vertical odd parity and horizontal even parity. Ten char/in.
[b]For ½", 200 bpi minimum, magnetic tape.

of a logic interface to a digital XY plotter. These combined equipments are shown in Figure 7. The reader has a speed of 300 char/sec, which matches the maximum plotter speed of 300 decrements/sec. A single decrement is equal to 0.01 inch. The plotter ignores the header data in the punched tape, but follows the vectorial instructions to produce an isocount contour map. Because the speed of the reader-plotter combination is so high, the data on an entire reel of tape, representing perhaps ten or more scans, can be read and plotted in about seven minutes. Repetitive plot-outs of the isocontour display are obtained by re-reading the processed data tape through the plotter. The header data are included in the tape for automatic print-out on the display by the typewritter after the contour map is removed from the plotter. The display is ready for diagnostic analysis after these final operations.[1]

In order to facilitate comparison of contour plots with the outputs of the photorecord and dot tapper the digital system, described in this paper, has been

[1]An alternative method provides for direct plotting of the header from tape prepared by semiautomatic transcription of alphanumeric logic codes from a master tape. This is effected through a "search-copy" option on the panel of the paper tape transmission unit, operating through the tape punch.

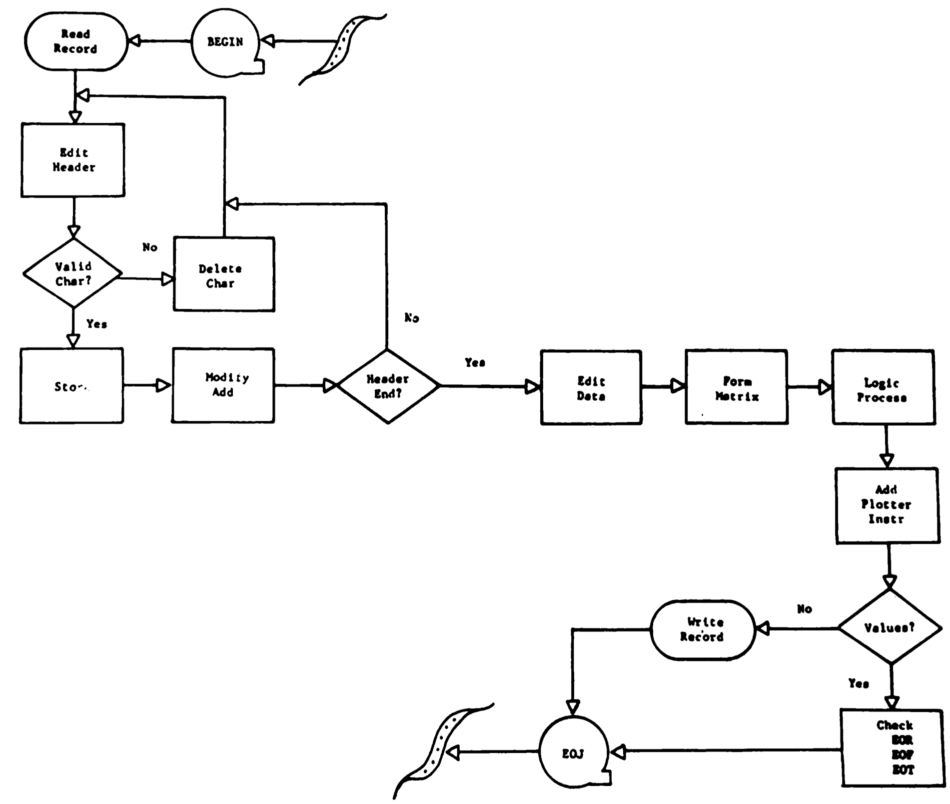

Fig. 6. Block diagram, scan data computer program.

designed to accept scanning pulses independently, but coincidental with the photorecording and dot tapper linkages. Since the pulse output of the detection apparatus is common to these circuits as well as to the digital Control Recorder Unit, the three different types of records can be obtained simultaneously, if desired, from identical pulses that enter each circuit at the same instant.[2]

DISCUSSION

Current literature describes a wide variety of analog, digital, and combined analog-digital scan recording methods. Often analog procedures may be used advantageously when a special purpose or interpretative result is desired. Yet, their major disadvantage lies in the fact that under clinical conditions it is not possible to establish for certain at the start whether the record about to be produced will be the most informative one possible. These restrictive conditions exist because those parameters which facilitate best interpretation are often difficult or impossible to preselect. Moreover, it seems unwise to regulate in advance the amount of scan information to be rejected. This is especially true in consideration of the potential scan volume obtainable through the instrumentation used.

In contrast, scan information obtained by digital recording may be transmitted, converted, processed, manipulated, or discarded to whatever degree the clinical situation demands. More importantly, the scan record has the advantage of not being subjected to an initial exclusion or rejection of information, as may be the case, for instance, when analog photorecording procedures are used.

Many of these advantages can be realized through the automatic system described, where computer processing procedures and automated programatic isocontour recording and display are used. This system acquires, records, and stores data nondestructively in a form suitable for computer processing so that it can be studied in detail at any time desired.

The digital record of accumulated counts and positional information is well suited to preparation of an isocontour activity map. This type of display record has the advantage that the statistical significance of the counts contours can be determined visually on the display and compared to the tape record. Since the relative distances between the display contour lines indicate the abruptness of the concentration changes, the isocount configuration also directs the eye to areas of relatively high or low activity.

Some of the features found in an isocount contour display are illustrated in Figure 8a, where a typical data reduction exercise has been manually simulated for thyroid tissue. In this diagram isocontour values were assigned to the contour lines after these were drawn. Because the distances between the contours

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[2]For example, comparison of identical count pulses, measured simultaneously but separately by the digital method and by a ratemeter, indicates that the ratemeter total of pulses recorded per unit time is less than that of the digital recording system. The number recorded varies downward to as low as 80% of the number detected and recorded by the digital Control Recorder Unit. The statistical variations of the ratemeter counts also appear to be greater. Conceivably, this difference could have some effect on the fidelity of photorecording.

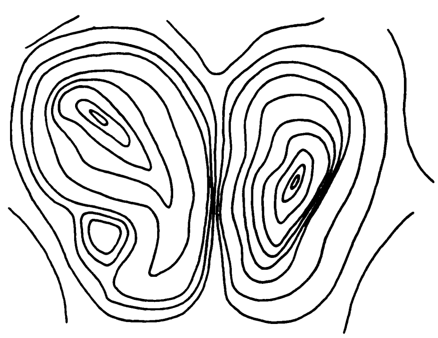
are not necessarily uniformly proportional to the numerical differences assigned to the isocount lines, "distortion" was, in effect, introduced into this figure. In order to test whether the computer program could modify or correct for this purposely inserted error pattern the data from the map in Figure 8a was recorded on tape, incorporated into the program, processed, and read into a plotter. The isocount contour map, shown in Figure 8b, reproduces the resultant count dis-

Fig. 7. The paper tape instructions control the plotter in accordance with the computer analysis.

tribution. Here the computer has compared the values presented to it and relocated them to isocount contours that are situated in corrected relative geographic relationship to each other. Hence the data processing reduced and removed the "distortion" purposely introduced into the left-hand figure.

Compared to automatic plotting procedures, manual plotting of an isocontour map has serious drawbacks. With computer processing, which corrects for deviant data, and fast plotting equipment, each contour can be matched quickly to its appropriate data value range without the need for human decision, which would be superfluous here. Manual plotting requires much care and time to ensure that each contour line will correspond accurately enough to a particular count range so that a usable record display is obtained. Because of this requirement, manual display preparation attains so slow a speed that the costs of manpower time become excessive. By increasing the labor time costs the expenses of scan preparation may become prohibitive, and thus limit markedly the number of scans that can be plotted and completed.

The data acquired in digital form is suitable not only for computer processing to produce isocontour map displays, but it is also adaptable to other types of computer analysis in different specialized programs. Thus it has the advantage that by selection of a specific program particular features of a scan can be emphasized in different display forms. However, even though the form of the type of display can be modified it is still possible to bring out additional interpretative features, still without loss of original data, if accentuation is carried out nondestructively by means of a "contrast enhancement" procedure, such as through a television monitor circuit or by photocopying.



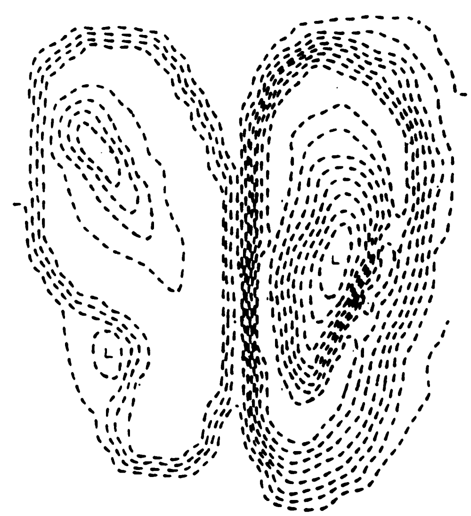


Fig. 8a. Isocount contour map of thyroid tissue: manual simulation.

Fig. 8b. Isocount contour map plotted from data figure on left: after processing in tape program.

SYSTEM APPLICATIONS

Although it is not envisioned that radioisotope isocontour or profile displays, prepared in the way that has been detailed, will be *the* ultimate single solution to scanning problems, they will assist in visual interpretation and analysis. The system procedures provide increased accuracy in scan data acquisition and recording, and in this way they can increase accuracy of definition and reduce display distortion. In addition, the rapid, dependable telecommunication facilities incorporated into the radioisotope scanning system is a feature that offers several important advantages if properly utilized.

Apart from its use for transmission of radioisotope scanning data outlined here, telecommunication facilities can be used to transmit a wide variety of other biomedical data. These capabilities for rapid transmission of data can be extended to include the possibility of use by several laboratories clustered about a centrally located computer. In this way the potential ability to solve many urgent biomedical problems rapidly and accurately can be increased many-fold. Only a few of the data-oriented problems that a telecommunication-computer net could help to solve need to be mentioned here briefly in order to illustrate its possible utility and advantages. For example, in a clinical test program many functional radioisotope measurements tests (bilateral renograms, cardiac function tests, blood studies, etc.) yield numerical output data that are readily introduced into computer program formats. Development and routine usage of these types of programs could facilitate, in turn, regional or national cooperative group studies to evaluate data comparatively or to establish experimental or standardized clinical study procedures. One of the most suitable fields where there is extensive need for the application of computer-centered telecommunication procedures is in programs for patient handling and traffic functions. These might include transmission and storage of patient records, or extended surveys for analysis of patient records to help evaluate treatment effects and trends.

Many factors influence the rational use of a data telecommunication net. Here, an indication of only a few of these will suffice. Differences in quantity or type of data analysis requirements will be closely related to the equipment needs and use for each individual station in a data net, but without prior planning and more exact definition of these requirements, they can be suggested here only in a relatively figurative manner.

The time-consuming characteristics of data collection, transmission, and data read-out operations also will be closely interrelated with the potential magnitude and character of the telecommunication net. In this regard, one factor which favors increased size of a data net is that the geographical differences between users permits many different procedures to be carried out simultaneously. However, another factor, which acts to limit the number of participating stations, is the total capacity of an individual station to collect data, for this capability is usually much less than the very great speed of most data processing equipment. Furthermore, the rate that data can be collected and introduced into the data processing complex will be measured not so much by the data source or type, but more by the measuring equipment characteristics, and by the amount of time that is devoted to data collection. For an example, if each station could collect data at the rate of 16 chars/sec, a rate typical of the system described in this report, and collected it for eight hours per day, then somewhat less than four 1000-ft reels of data could be accumulated by any one laboratory. This would require about four hours to-and-from transmission time, and on this basis alone it would be practicable for only two stations to operate conjointly to a single computer. However, it is extremely difficult to envisage that data could be collected so continuously, or that so much radioisotope would be utilized in most clinical situations to require this data collection rate. It would be more reasonable to anticipate a lower figure of about one reel of data for data collection capability. This would amount to 1.2×10^5 recorded chars, a quantity of data that would still require a considerable time for accurate interpretation and analysis. To introduce, process, and retrieve this amount of data from the data processing center would take about one hour, and as a result, a conservative estimate for data net size would be about eight stations. Obviously, any estimate of this type is subject to much revision to conform to actual operational conditions.

The criteria so briefly touched upon here, and others that also bear upon the establishment and use of a data telecommunication net will require refined study before final answers can be reached. Their analysis is the object of several current feasibility studies.

SUMMARY

A system for automatic transmission, computer processing, and transformation of radioisotope scanning data for final display in contour map form has been developed to evaluate its use and capabilities for biomedical data measurement. It employs an existing scanning, recording and telecomputing configuration to prepare automatically two-dimensional isocount contour maps from computer-processed radioisotope scan data.

The experimental scanning system is comprised of four functional sections: (1) Data Collection Station, (2) Transmission System, (3) Computer Processor, and (4) Display Plotter Device. These components and their operation are described and discussed.

The research configuration is utilized to compare and evaluate the effects of (1) count density, (2) count interval time, (3) scanner speed, and (4) definition capabilities in scans performed with phantoms, organs, or on patients presented for clinical diagnosis. By introduction of these data into the automated bioelectronic data collection, telecomputing and display system, improvements in the speed and accuracy of analysis of radioisotope scan data will be demonstrated.

Some capabilities of this system to incorporate a variety of other biomedical data into the present or a modified expanded telecommunication/computer system are briefly presented and discussed.

REFERENCES

1. BRUCER, M.: Radioisotope Scanning, *U.S. Atomic Energy Commission Document, ORINS-20,* 1958.

2. International Atomic Energy Agency: *WHO Seminar on Medical Radioisotope Scanning,* Vienna, 226 pp., 1959.
3. WAGNER, H. N., JR., MCAFEE, J. G., AND MOZLEY, J. M.: Medical Radioisotope Scanning, *J. Am. Med. Assoc.* **174**:162, 1960.
4. WAGNER, H. N., JR.: in *Practice of Medicine, II,* W. F. Prior Co., Inc., Hagerstown, Md., 588 pp., 1962.
5. BASCHIERI, I., AND D'APUZZO, B.: Possibilities and Limitations of Scintigraphy *Nucl-Med.* **2**:290, 1962.
6. PIRCHER, F. J., BRUCER, M., MORRIS, A. C., JR., AND BLACK, R.: The Orins Linear Scanner in Clinical Diagnosis, *J. Nuclear Med.* **3**:26, 1962.
7. KRISS, JOSEPH P.: Radioisotope Scanning in Medical Diagnosis, *Ann. Rev. Med.* **14**:381, 1963.
8. KNISELEY, RALPH M., ANDREWS, GOULD A., AND HARRIS, C. CRAIG, Eds., Progress in Medical Radioisotope Scanning, *U.S. Atomic Energy Commission Document TID-7673,* 1963.
9. SHY, G. M., BRADLEY, R. B., AND MATTHEWS, W. D., JR.: in *External Collimation Detectection of Intracranial Neoplasis with Unstable Nuclides,* E. & S. Livingstone Ltd., Edinburg and London, 148 pp., 1958.
10. MACINTYRE, W. J., CRESPO, G. G., AND CHRISTIE, J. H.: The Use of the Counting Rate Profile in Radioisotope Scanning Techniques, *J. Nuclear Med.* **1**:262, 1960.
11. KUHL, D. E., CHAMBERLAIN, R. H., HALE, J., AND GORSON, R. O.: A High-Contrast Photographic Recorder for Scintillation Counter Scanning *Radiology,* **66**:730, 1956.
12. BENDER, M. A.: Photoscanning Detection of Radioactive Tracers In Vivo, *Science,* **125**: 443, 1957.
13. ALLEN, H. C., JR.: In *Symposium, U.S. Naval Medical School,* National Naval Medical Center, 1958.
14. CASSEN, B., CURTIS, L., REED, C., AND LIBBY, R.: Instrumentation for I^{131} in Medical Studies, *Nucleonics,* **9**:45, 1951.
15. JACOBS, M. E., ORVIS, A. L., AND BORRMAN, B. B.: Electronic Recorder for the Gammagraph, *Nucleonics,* **12**:60, 1954.
16. HARRIS, C. C., FRANCIS, J. E., AND BELL, P. R.: Problems Encountered in In Vivo Localization of Radioactivity and Solutions to a Few of them, *Texas Eng. Expt. Sta. Misc. Publ. E72-60,* 62, 1960.
17. MAYNEORD, W. V., AND NEWBURY, S. P.: An Automatic Method of Studying the Distributions of Activity in a Source of Ionizing Radiation, *Brit. J. Radiol.* **25**:589, 1952.
18. MACINTYRE, W. J., *et al:* Techniques for the Visualization of Internal Organs by an Automatic Radioisotope Scanning System, *Intern. J. Appl. Radiation and Isotopes,* **3**:193, 1958.
19. HERRING, C. E.: A Universal Photorecording System for Radioisotope Area Scanners, *J. Nuclear Med.,* **1**:83, 1960.
20. ANGER, H. O.: Use of a Gamma Ray Pinhole Camera for In Vivo Studies, *Nature,* **170**: 200, 1952.
21. JAFFEE, H. L., CLARK, S. H., AND PAPE, L.: Radioiodine Uptake and Thyroid Scintigram with a Single 30 Microcurie Dose, in *Report, Third Annual Meeting, Soc. Nuclear Med.,* 1956.
22. MALLARD, J. R., AND MYERS, J. J.: Scanning Techniques With a Gamma Camera and Color Scintiscanner, in *Abstracts, Tenth Intern. Congress of Radiology,* 35, 1962.