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REFERENCES

1. Haaga JR, Alfidi RJ, Havrilla TR, et al: Definitive role of CT scanning of the pancreas: the second year's experience. Radiology **124:**723–730, Sep 1977
2. Haaga JR, Alfidi RJ, Zelch MG, et al: Computed tomography of the pancreas. Radiology **120:**589–595, Sep 1976
3. Ferrucci JT Jr, Wittenberg J, Black EF, et al: Computed body tomography in chronic pancreatitis. Radiology **130:**175–182, Jan 1979
4. Stanley RJ, Sagel SS, Levitt RG: Computed tomographic evaluation of the pancreas. Radiology **124:**715–722, Sep 1977

[1] From the Department of Radiology, St. John's Hospital and Health Center, Santa Monica, Calif. (Address reprint requests to R.D.A., Dept. of Radiology, St. John's Hospital and Health Ctr., 1328 22d St., Santa Monica, CA 90404.) Received June 12, 1980, and accepted Sept. 23.

[2] Squibb, Princeton, N.J. sb

Continuous Image Recording Using Gray-Tone, Dry-Process Silver Paper[1]

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A method of recording continuous gray-tone images on dry-process silver paper from raster-scan video signals is described. The Tektronix 4634 image-forming module uses a fiber-optic faceplate cathode-ray tube to couple the light output onto the recording paper. The latent image is heat developed and presented in sheet form. An initial comparison between dry silver paper and conventional film for video-generated computed tomography and nuclear medicine examinations, shows little apparent difference in image quality. Considerable cost savings are possible when using dry silver paper. Additional cost savings are possible if multiple images can be recorded on each dry silver sheet.

INDEX TERMS: Computed tomography, display systems • Economics, medical • Nuclear medicine, instrumentation

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Multiple-format film recorders are in common use for imaging video raster-scan information from computed tomography (CT) scanners, ultrasound scanners, and nuclear medicine gamma cameras. The rising cost of conventional film and film processing has prompted our investigation of dry-process silver paper as an alternative image-recording medium.

IMAGE RECORDER

The dry silver-paper images were obtained with a Tektronix 4634 image-forming module which can record continuous, gray-tone images from raster-scan video signals (1). The unit uses a cathode-ray tube (CRT) with a fiber-optic faceplate (Fig. 1) to couple the light output onto the dry silver material. The latent image is heat developed and ejected on a sheet through an opening in the front panel of the module.

The form of the video information may be composite, separate with composite synchronization, or with horizontal and vertical drive. The instrument processes the video signal and produces successive lines of image information. A small portion of every raster line of a video frame can be displayed at any time on the CRT (Fig. 2). This window is similar to a vertical strip moving across the raster lines on a monitor. The diameter of the fiber-

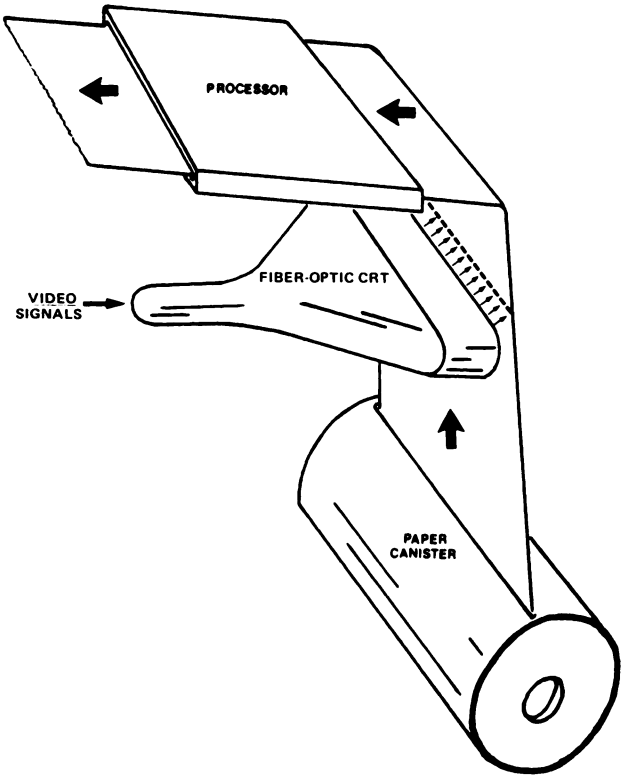

Fig. 1. The dry silver-paper recorder, using a CRT with a fiber-optics faceplate.

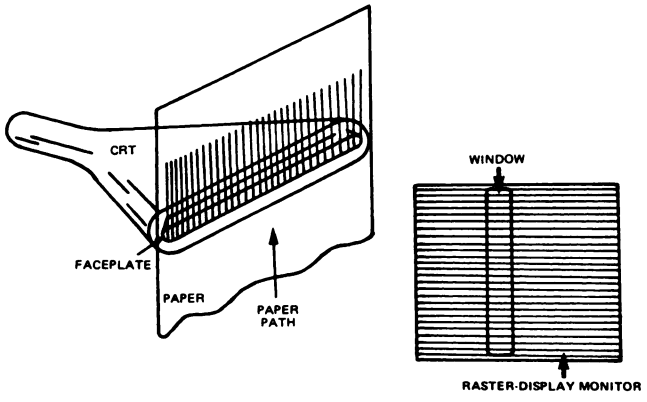

Fig. 2. Paper path across the CRT and window of the Tektronix 4634 image-forming module.

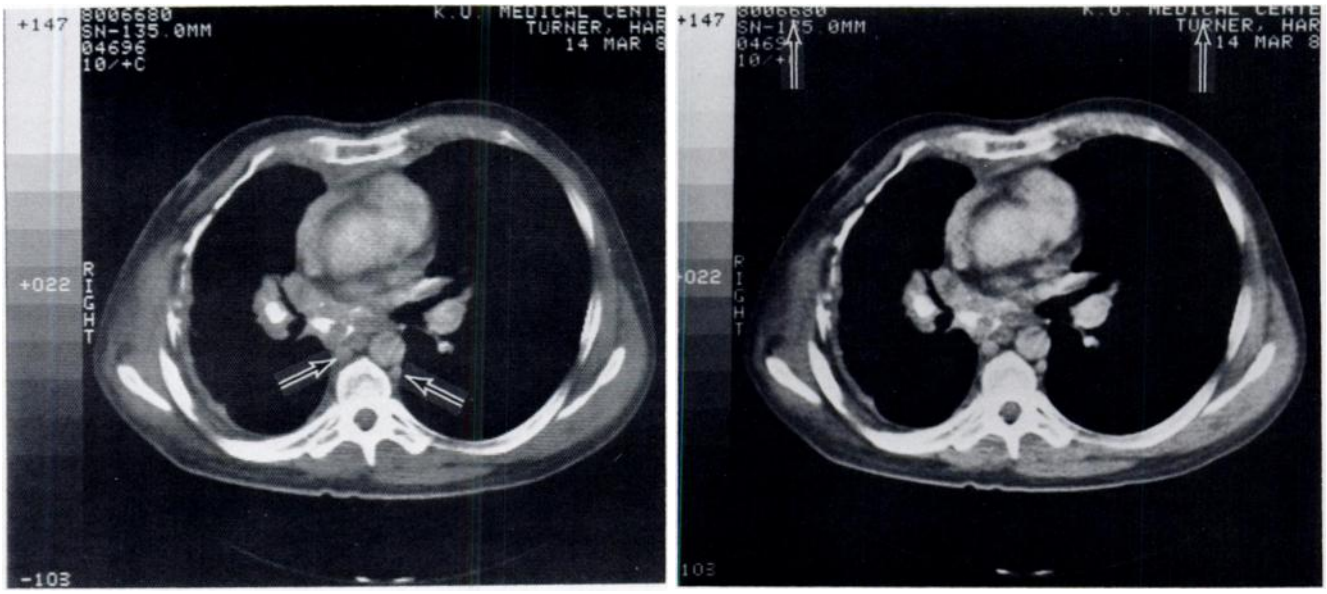

Fig. 3. **a.** CT scan after administration of contrast material, recorded on dry silver paper, demonstrating extensive calcification in the mediastinal and right hilar nodes and enlarged collateral venous channels (arrows) in a patient with superior vena caval syndrome.
b. The image of the same scan recorded on film, showing slightly higher contrast but lesser sharpness and edge distortion (arrows).

optic fiber is 10 μm (4×10^{-4} in.).The CRT has a spot size of less than 0.15 mm (0.006 in.); the grid drive on the CRT is powered by 10 V. Luminance variation across the fiber-optic faceplate is less than 1.3 to 1. Video line rates are adjustable from 525 to 1,029 at 2:1 interlaced or 256 to 512 noninterlaced. The instrument pulls the dry silver paper out of a storage canister and past the face of the CRT; consequently, successive sections of paper are exposed to successive lines of the image, creating a latent image on the paper.

During the scanning operation, the video image must remain stationary. Exposure time is 8.5 seconds with an additional 17.5 seconds required to develop an 11-inch (27.9-cm) hard copy. The instrument requires a 20-minute warm-up period to ensure that the thermal processor has stabilized at the proper operating temperature.

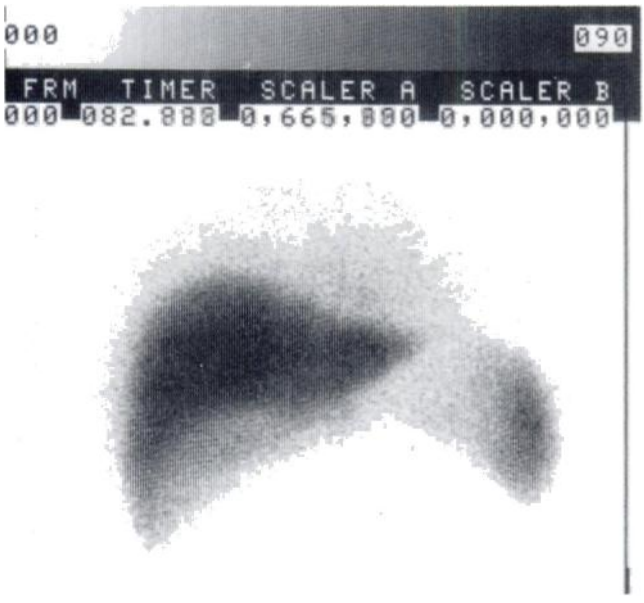

Fig. 4. Normal static AP view of the liver and spleen as recorded on dry silver paper at one-million counts.

The front panel has three adjustments. The DEV TEMP knob adjusts the thermal processor temperature to compensate for roll-to-roll variations in the developing rate of the paper. The BRIGHTNESS adjustment changes the average brightness of the image. The CONTRAST knob adjustment allows the user to choose the amount of contrast desired between the light and dark portions of the image; this adjustment is intended to account for individual preferences.

DRY SILVER-RECORDING PAPER

The Tektronix 4634 image-forming module uses a dry-process silver paper manufactured by the Minnesota Mining and Manufacturing (3M) Company. The 3M paper is available in either type 7772 or type 7770 (1) and is packaged in a roll encased in a light-sealed cylindrical cassette. Each paper roll is 500 feet (152 m) in length which provides approximately 545 eleven-inch (27.9-cm) sheets. The characteristics of type 7772 paper include (*a*) a maximum optical density of 1.45 and a minimum optical density of 0.20, (*b*) 12 measurable gray-scale levels, each step separated by at least one standard deviation of density from the adjacent input step, and (*c*) a resolution of at least 4.92 lines/mm (125 discernable lines/in.). The characteristics of type 7770 paper include (*a*) 6 distinguishable levels of gray with 10 linear input steps and (*b*) a resolution of at least 3.94 lines/mm (100 discernable lines/in.).

The length of each copy can be adjusted from 7 to 11 inches (17.8 to 27.9 cm) in 3/4-inch (19-mm) increments. The horizontal image size can be adjusted from 5 to 8 inches (12.7 to 20.3 cm). The paper width is 8.5 inches (21.6 cm). The vertical image size is adjustable for varying aspect ratios.

TABLE I: COMPARISON OF DRY SILVER-PAPER RECORDED CT SCANS AND NUCLEAR MEDICINE EXAMINATIONS WITH MULTIFORMAT FILM RECORDINGS

	Tektronix 4634 Image-Forming Module	GE Multiformat CT Body Film Recorder	Searle Nuclear Medicine Multiformat Film Recorder
Recorder instrumentation cost	$12,000*	$30,000*	$8,000†
Recording media cost	$0.21 per sheet of 3M type 7772 (based on current price of $110 per roll of 500 ft. [152.4 m] which generates 545 eleven-in. [27.9-cm] copies)‡	$3.35 per sheet of 14 × 17-in. (35.6 × 43.2-cm) film used by the film recorder	$1.18 per sheet of 8 × 10-in. (20.3 × 25.4-cm) Kodak Nuclear Medicine Blue (NMB) film used by the film recorder
Cost of developing copies	–	$0.32 per 14 × 17-in. (35.6 × 43.2-cm) sheet of film	$0.23 per 8 × 10-in. (20.3 × 25.4-cm) sheet of film
Number of images	One recorded TV image per sheet (possible to record multiple images per copy)	Twelve recordings per 14 × 17-in. (35.6 × 43.2-cm) sheet of film (11 CT scans plus 1 input-data block)	Up to 16 recordings per 8 × 10-in. (20.3 × 25.4-cm) sheet of NMB film
Labor and time to generate recorded copy	26 sec. (12-sec. repeat rate)	Film cassette must be loaded, exposed, and developed	Film cassette must be loaded, exposed, and developed
Reading of recorded images	Reflected light (normal room light)	Back lighted (view boxes)	Back lighted (view boxes)
Image quality	Thirteen to 14 gray levels (recorded from the step wedge on the display monitor)	Sixteen to 18 gray levels (recorded from the step wedge on the display monitor)	Sixteen gray levels (recorded from the step wedge on the display monitor)
Storage	Folder in film jacket	Film-jacket storage	Film-jacket storage

* The list price is provided by General Electric Company, Medical Systems Division, Milwaukee, Wisc.
† The list price is provided by Searle Corporation, Des Plaines, Ill.
‡ The current list price is provided by Tektronix, Inc., Beaverton, Ore. Dry silver paper fluctuates in cost due to the price of silver. The expense will be much less than film.

RECORDING CT IMAGES

The recorder module was connected easily to the display monitor of our GE 8800 CT body scanner by a single video cable. The GE display monitor operates at a nonstandard, noninterlaced video line rate. A screw adjustment permits the Tektronix recorder to change from interlaced to noninterlaced video frames, and another adjustment provides for the reduction of space between raster lines when using noninterlaced video.

We recorded a number of CT scans and compared the dry silver recordings (Fig. 3a) to those of the GE multiformat film recorder (Fig. 3b). Initial observations regarding the use of the dry-process recorder included the following:

1. The type 7772 paper recorded 13 to 14 steps of the gray-scale wedge generated for display on the GE CRT. The corresponding film recording, when properly back lighted, provided a visual detection of 16 to 18 gray-scale steps.

2. Unlike the images processed in the film recording mode, the dry silver paper recorded the individual raster video line more clearly and eliminated edge distortion due to the surface curvature of the CRT (Fig. 3b). Thus the images recorded on the silver paper were slightly lower in contrast and sharper in resolution than those on the film (Fig. 3, a and b). However, during our limited study, we were unable to detect any significant difference in the image quality when comparing the silver paper and the back-lighted film recording. If identical dry silver paper and gray-scale film recordings are to be achieved, then the step-wedge display algorithm for CT should be modified.

3. We had to become accustomed to handling paper-copy recordings. Each CT scan was recorded on one sheet of paper. The GE multiformat video film camera uses a 14 × 17-inch (35.6 × 43.2-cm) sheet film which records 12 exposures (11 images; 1 identification block). The average number of precontrast and postcontrast CT scans of the abdomen is between 35 to 40 images. Multiple CT images can be recorded on the dry silver paper if the proper display software is added to current CT display systems.

CT images using dry silver paper have several advantages:

1. A dry silver recording can be made for each scan, mounted in a folder, and reviewed by the radiologist. If the scans are normal, the folder can be placed in the film jacket as part of the patient's record. If the CT scans are abnormal, selected images can be recorded on film using the multiformat film recorder.

2. Instead of film copies, dry silver images can be sent to outside referring physicians.

3. Multiple CT scans can be recorded on each of the dry silver images. This requires that the current display station software be modified so as to ensure adequate digital resolution of the recorded CT scans. The Dynamic Scan Capability software

TABLE II: AVERAGE COST OF CT SCAN RECORDINGS PER YEAR

	Cost of Recorder per Exam	Cost of Recorder Maintenance per Exam	Recording Media Cost per Exam	Media Processing Cost	Cost of Film Processor per Exam	Media Storage	Estimated Labor Cost	Cost per Exam	Cost per Year
ltiformat video film recorder	$1.79*	$0.54†	$10.05‡	$0.90§	$0.59**	0	$0.88††	$14.75	$49,560
y silver-paper video recorder	$0.71‡‡	$0.21§§	$5.25*** $2.73†††	0	0	$0.06‡‡‡	0	$6.23*** $3.71†††	$20,932*** $12,466†††

($30,000 [cost]/5 years [prorated])/3,360 CT exams per year = $1.79 per exam
($30,000 [cost] × 6% [maintenance cost per year])/3,360 CT exams per year = $0.54 per exam
3 films × $3.35 per film = $10.05
3 films × ($0.15 [chemicals] + $0.15 [film-processor maintenance]) = $0.90
* ($9,945 [cost of Kodak M7B film processor]/5 years [prorated])/3,360 CT exams per year = $0.59 per exam
† The estimated labor cost per exam for loading and developing three film cassettes is $0.88 ($3.50 per hour and 5 minutes per cassette).
‡ ($12,000 [cost]/5 years [prorated])/3,360 CT exams per year = $0.71 per exam
§ ($12,000 [cost] × 6% [maintenance cost per year])/3,360 CT exams per year = $0.21 per exam
**25 CT scans (average number to be recorded) × $0.21 per sheet (1 CT scan per sheet) = $5.25
†† If 2 CT scans are recorded per sheet, the cost is $2.73.
‡‡ Cost of folder for properly storing dry silver paper in a film jacket

E CT/T^2 provides for the simultaneous display of up to nine scans. Both digital- and analog-image information could be ommodated.

CORDING NUCLEAR MEDICINE EXAMINATION IMAGES

he dry silver paper recorder was also connected easily to display monitor of the Searle Radiographics LFOV Gamma era System using a single video cable. The Searle display itor operates at an interlaced video line rate of 525. Paper ge recordings were black and white. A number of nuclear licine scans were recorded, and the dry silver images (Fig. ere compared to those from the Searle multiformat film rder. The dry silver paper provided slightly low-contrast, -resolution images which were similar to those noted for the cans. We believe that the step-wedge display algorithm of display monitor may not need readjustment, as 13 to 14 ls of gray-scale are adequate for interpretation of nuclear licine scans. Although nuclear medicine imaging studies narily require less film per exam than CT, significant cost ngs could also be achieved if dry silver paper could be stituted for conventional film.

COST COMPARISONS

/e have conducted an initial comparison in the use of dry r paper as compared to multiformat film. These results are marized in TABLE I. In developing an initial cost comparison, following assumptions were made:

. For each CT body examination, the average number of scans per patient was 25, and 280 CT examinations were ormed each month (3,360 each year).

. For each gamma camera, the average number of nuclear licine images per patient was 20, and 200 nuclear medicine minations were performed each month (2,400 each year).

. The cost of a multiformat video film camera would be ated over five years and that a maintenance contract would % per year of the original equipment cost.

4. The cost of a film processor would be prorated over five years.

TABLE II provides a cost comparison between the use of dry video film and dry silver paper for CT scans. The cost ratio is 2.35 ($49,123 as compared to $20,932). If two CT scans could be recorded on two dry silver sheets (requiring modification in the CT display station software), the cost ratio would be 3.97 ($49,590 as compared to $12,466). Multiformat cameras will probably not be abandoned immediately, but both recording media can be utilized. For example, one might use the dry silver paper for all CT scans ($3.71 per exam with two CT scans per sheet) while use of the film recorder would be limited to one image (11 CT recordings plus 1 identification block at $6.82 per exam). The cost ratio for nuclear medicine images was calculated in a similar manner and proved to be 3.36 ($16,032 as compared to $4,776).

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REFERENCE

1. Eriksen J: Making a hard copy from a raster scan monitor. Electro-Optical Systems Design **12**:37–44, Jul 1980

[1] From the Department of Diagnostic Radiology, University of Kansas Medical Center, Kansas City, Kan. (Address reprint requests to K.R.L., Dept. of Diagnostic Radiology, Univ. of Kansas Medical Center, Rainbow Blvd. at 39th St., Kansas City, KS 66103.) Received May 9, 1980, and accepted Aug. 21.

[2] B7815 Dynamic Scan Capability. Preliminary product data. General Electric Company, Medical Systems Division, Milwaukee, WI 53201

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