FINAL REPORT

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Principal Investigator: Norman A. Baily
Professor of Radiology

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(NASA-CR-139664) [RESEARCH PROGRESS IN RADIATION DETECTORS, PATTERN RECOGNITION PROGRAMS, AND RADIATION DAMAGE DETERMINATION IN DNA] Final (California Univ.) 17 p HC $4.00 CSCL 06R G3/04 N74-31569 Unclas 47855

INTRODUCTION

A chapter was prepared for publication in the next edition of Advances In Radiation Biology entitled, "The Radiological Implications of Statistical Variations in Energy Deposition by Ionizing Radiations."

The completed multiwire proportional counter has undergone preliminary testing in the laboratory using a ^{212}Po alpha source. All aspects of its performance seem to be satisfactory.

Studies of the minimum detectability which can be achieved by the digitized x-ray fluoroscopy system have been completed. The studies were conducted using thick water phantoms (10 cm, 15 cm, and 20 cm). These limits were determined for aluminum, air, and three concentrations of Renografin-60 (10%, 25%, and 50%).

Pattern recognition programs have been developed for measurement of gall-stone volumes, bronchi diameters, and vessel diameters. These can be used either with film or by direct processing of the video signal derived from a fluoroscopic screen.

A large flat-screen (14" x 17") fluoroscopic image intensification (x-ray) system has been built and undergone preliminary testing. Performance and sensitivity is better than conventional systems.

One experimental run was made utilizing the UCLA medical cyclotron for determining DNA damage from proton irradiations. The beam was calibrated using an extrapolation chamber so that direct comparison of these results with those obtained using x-rays can be made on the basis of macroscopic exposures. These experiments are designed to test a radiobiological model incorporating stochastic fluctuations of energy deposition for passage of heavy charged particles through biologically significant sites.

RESEARCH SUMMARY

1. Microdosimetry

The chapter, "The Radiological Implications of Statistical Variations in Energy Deposition by Ionizing Radiations", to be published in the new edition of ADVANCES IN RADIATION BIOLOGY ~~is attached as~~ (Appendix I removed). ~~The work~~ should appear in June 1974. This chapter was written to emphasize the concepts and results developed under the sponsorship of this grant in contrast to the more traditional dosimetric concepts.

One rather large area requires detailed experimental study to complete the physical picture. This is a detailed study of the production of and contributions due to secondary particle production generated by the passage of the primary radiation through the site of interest. To carry out these experiments a multiwire proportional counter capable of simulating volumes corresponding to biological sites has been constructed and tested in the laboratory. Initially, studies using radioactive sources will be continued in the laboratory. Following these, we intend to carry out studies using the UCLA cyclotron which will provide; 27 MeV ^{3}He, 22 MeV protons, 22 MeV α particles, and 11 MeV deuterons. If sufficient funding is available higher energy particle beams at SREL and at Berkeley will be used.

The experimental results using 45 MeV protons comparing frequency distributions of energy deposition for bone and muscle were included as Appendix A in our semi-annual report.

2. Radiation Biology

Our cooperative experimental program involving Dr. K. Wheeler of UCSF has been initiated. Proton irradiations at the UCLA cyclotron have been carried out. These are designed to study the ratio of non-reparable to reparable damage in DNA as a function of different energy deposition patterns generated by x rays vs. heavy fast charged particles.

Preliminary results indicate considerable differences exist and these are what would be predicted from the energy deposition distribution functions.

3. Radiobiological Models

The work done on such models is presented in parts 5 and 6 of Appendix I.

4. Electronic Radiography

The use of the electronic radiography system for direct fluoroscopic tomography and for the synthesis of multiple planes has been described in Appendix B of the semi-annual report. The use of this system for cutting body sections through organs in motion should be of particular value to the NASA for cardiovascular studies.

A complete study of the digitized system for detection and quantitation of small changes in tissue masses has been undertaken. The early work was described in Appendix C of the semi-annual report.

Another set of experiments was designed to determine the characteristics of the system's response to split fields having different contrast levels and to determine the minimum detectable contrast levels between the halves under realistic clinical situations. The experimental set-up is shown in Fig. 1. The target-to-tabletop distance was 40 inches. The dimensions of the water phantom were 50 cm x 50 cm x 50 cm. In all experiments the field size was 10 cm x 10 cm at the tabletop. The absorbers or air cavities were placed so as to cover half of the x-ray field and centered at the midpoint of the water scatterer. The water depth ranged between 10 cm and 20 cm, thereby introducing scattering comparable to that which would be present in a clinical situation. The contrasts calculated are all referred to the unperturbed half of the field. Experiments were conducted using aluminum (as an approximation for bone), Renografin-60, and air.

The results are shown in Figs. 2 through 5. The values of the ordinate were computed by selecting two adjacent areas occupying a tabletop area of 1.5 cm^2 (320 picture elements) each having its horizontal center line at the center of the x-ray field and interior edges 1 cm from the absorber or cavity edge.

Fig. 2 shows the response curves obtained for aluminum absorbers. A was obtained using 120 kVp and a water depth of 20 cm. B represents the data for 100 kVp and 15 cm of water. C was obtained using 90 kVp and 10 cm of water.

Fig. 3 shows the results for various concentrations of Renografin-60. A is for a 10 percent solution, B for 25 percent, and C for 50 percent. The thickness of the water phantom was 20 cm and the tube potential 120 kVp. The Renografin-60 solutions were contained in plexiglass containers having a thickness of 0.25". These were supported on a platform of 0.25" polystyrene. Equal thicknesses of these materials were placed in the other half of the field and the water level reduced accordingly.

Figs. 4 and 5 show the results obtained with air cavities. The geometry was identical to that used to obtain the Renografin-60 data. Fig. 4 shows the complete response while Fig. 5 shows the data obtained for thin cavities on an expanded scale. The data in Fig. 4 was obtained using 120 kVp and 20 cm water. Curve A, in Fig. 5 is the same data plotted on an expanded scale, while B is that obtained using a potential of 100 kVp and 20 cm water.

Using the slope of the initial straight portions of these curves (or straight lines), one can obtain a value for the minimum degree of contrast that can be reliably differentiated in each case. We choose to use a value of two standard deviations to determine these. The results are shown in Table I. In all cases less than 1 mm of material can be detected even in the presence of a large scattering volume. In previous work we have found that the addition of a 12:1 moving grid was found to improve the contrast of the image substantially.

However, in clinical use this would, of course, increase the patient dose. We have not measured this effect quantitatively.

In all cases the response, when treated as contrast, shows a linear response with absorber thickness up to considerable thicknesses. This is not a case of small absorber thickness giving a truly exponential response and being approximated by a linear function. The data does not plot linearly when treated semi-logarithmically. If we ignore scattering and other perturbing factors such as curvature of the input screen and inverse square effects, the conatrast or relative video signal levels are given by:

$$C = 1 - e^{\mu_2 t} e^{-\mu_1 t} \qquad (1)$$

where; μ_2 = attenuation coefficient of water

μ_1 = attenuation coefficient of absorber

t = absorber thickness.

For small t, this reduces to:

$$C = \mu_1 t(1 + \mu_2 t) - \mu_2 t \qquad (2)$$

At larger thicknesses the response does not remain linear but decreases in the case of absorbers which are more dense or have a greater linear absorption coefficient than water and increases more rapidly with cavity size in the case of air. In the manner in which our data was computed Equation (1) becomes for air cavities,

$$C = 1 - e^{-\mu_2 t} e^{\mu_1 t} \qquad (1^1)$$

and for small cavities,

$$C = \mu_2 t (1 - \mu_1 t) - \mu_1 t \qquad (2^1)$$

where; μ_1 = attenuation coefficient of air

t = cavity thickness

The minimum detectable contrast seems to be mainly limited by scatter and electronic noise. Both of these are amenable to improvements in the experimental set-up. However, decreasing scatter by the addition of a grid with a higher ratio would involve an increase in patient dose. Signal-to-noise ratios can be increased by any number of electronic improvements in circuitry, system configuration, and digitization equipment.

The linearity of the system's response to changes in contrast over a rather large range of clinically interesting values will tend to make quantitative determinations simple, accurate, and allow extrapolation of experimental data for other calculations. The values given in this paper would certainly be different using another system or with a change in components. However, we feel the values given, the form of the system's response, and minimum detectable contrasts are typical of what can be expected from this type of system.

CONCLUSIONS

1. The response of digitized fluoroscopic imaging systems is linear with contrast over a rather wide range of absorber and cavity thicknesses.

2. Contrast changes associated with the addition of aluminum, iodine containing contrast agents and air of thicknesses 1 mm or less can be detected with a 95% confidence level.

3. The standard deviation associated with such determinations using clinically available x-ray generators and video disc recording is less than 1 percent.

A large flat screen x-ray image intensifier has been constructed and some preliminary results obtained. Sensitivity achieved makes dose reduction a factor often greater than previously reported for our system using a conventional x-ray image intensifier. A paper describing these results and a comparison of the images obtained with that of the conventional device will appear shortly in the bulletin of the SPIE.

PAPERS PRESENTED AT MEETINGS

1. Detection Capability of Differential Radiographic Absorption Through the Use of Fluoroscopic Images, Crepeau, R.L., Baily, N.A., 12th Ann. San Diego Biomed. Symp.
2. Frequency Distributions of Energy Deposition by 44 MeV Protons at Bone-Soft Tissue Interfaces, Baily, N.A., Steigerwalt, J.E., and Hilbert, J.W., 1973 Annual Meeting of the AAPM.
3. Electro-Fluoroplanigraphy, Baily, N.A., Lasser, E.C., and Crepeau, R.L., 1973 Annual Meeting of the AAPM.
4. The Calculation of Proportional Counter Energy Deposition Spectra from Experimental Data, Steigerwalt, J.E., and Baily, N.A., 1973 Annual Meeting of the AAPM.
5. Differential Radiographic Absorption Measured From Digitalized Fluoroscopic Images, Crepeau, R.L., and Baily, N.A., 1973 Annual Meeting of the AAPM.
6. Electronic Tomography, Baily, N.A., Crepeau, R.L., and Lasser, E.C., Symp. on Electronic Imaging Techniques in Diagnostic Radiology, Univ. of Pittsburgh, 1973.

PAPERS PUBLISHED

1. Applications of A Digitalized Radiographic-Fluorographic Processing System to Physiologic Data Extraction, Crepeau, R.L., Baily, N.A., and Silverman, N.R., Proc. of the San Diego Biomed. Symp., <u>11</u>: 317-322 (1972).
2. The Calculation of Proportional Counter Energy Deposition Spectra From Experimental Data, Steigerwalt, J.E., Baily, N.A., Rad. Res. <u>51</u>: 480 (1972).

3. A Video-Roentgenography System For Special Procedures and The Acquisition of Quantitative Data, Baily, N.A., Lasser, E.C., and Crepeau, R.L., Proc. of the 3rd Int. Conf. on Medical Physics, Gothenburg, Sweden, 1972, 2.7 (1972).

4. Electro-Fluoroplanigraphy, Baily, N.A., Lasser, E.C., and Crepeau, R.L., Radiology 107: 669-671 (1973).

5. The Calculation of Proportional Counter Energy Deposition Spectra From Experimental Data, Steigerwalt, J.E., Baily, N.A., Rad. Res. 53: 1-14 (1973).

6. Detection Capability of Differential Radiographic Absorption Through the Use of Fluoroscopic Images, Crepeau, R.L., Baily, N.A., Proc. of the 12th San Diego Biomed. Symp., 277-283 (1973).

7. Frequency Distributions of Energy Deposition by 44 MeV Protons at Bone-Soft Tissue Interfaces, Baily, N.A., Steigerwalt, J.E., and Hilbert, J.W., AAPM Quarterly Bull. 7: 101 (1973).

8. Electro-Fluoroplanigraphy, Baily, N.A., Lasser, E.C., and Crepeau, R.L., AAPM Quarterly Bull. 7: 91 (1973).

9. The Calculation of Proportional Counter Energy Deposition Spectra from Experimental Data, Steigerwalt, J.E., Baily, N.A., AAPM Quarterly Bull. 7: 101 (1973).

10. Differential Radiographic Absorption Measured From Digitalized Fluoroscopic Images, Crepeau, R.L., Baily, N.A., AAPM Quarterly Bull. 7: 91 (1973).

11. The Calculation of Proportional Counter Energy Deposition Spectra From Experimental Data. II. Very Small Energy Losses and High Energy Delta Rays, Baily, N.A., Steigerwalt, J.E., Rad. Res. 56: 213-221 (1973).

12. Frequency Distributions of Energy Deposition by 44 MeV Protons at Bone-Soft Tissue Interfaces, Baily, N.A., Steigerwalt, J.E., and Hilbert, J.W., Rad. Res. 56: 205-212 (1973).

13. An Electro-Fluoroplanigraphy System For Clinical Use, Baily, N.A., Lasser, E.C., and Crepeau, R.L., Invest. Radiol. 8: 276-277 (1973).

PAPERS IN PRESS

1. Electronic Tomography, Baily, N.A., Crepeau, R.L., and Lasser, E.C., Proc. of the Symp. on Electronic Imaging Techniques In Diagnostic Radiology.

2. The Radiobiological Implications of Statistical Variations In Energy Deposition By Ionizing Radiations, Baily, N.A., Steigerwalt, J.E., Advances in Radiation Biology Vol. V.

3. Performance of a Large Screen Fluoroscopic Imaging System, Baily, N.A., Crepeau, R.L., Proc. of the SPIE.

4. Capabilities of Fluoroscopic Systems to Determine Differential Roentgen Ray Absorption, Baily, N.A., Crepeau, R.L. Radiology.

PERSONNEL PARTICIPATING IN PROGRAM

1. Norman A. Baily, Professor of Radiology
2. John E. Steigerwalt, Assistant Research Radiation Physicist
3. Ronald L. Crepeau, Assistant Developmental Engineer
4. Earl M. Raeburn, Lab Technician
5. Elliott C. Lasser, Professor of Radiology

FIGURE CAPTIONS

Fig. 1 Water phantom used to determine system response to variations in contrast levels.

Fig. 2 System response to varying contrast levels produced by aluminum absorbers.

A: 120 kVp, 20 cm water scatterer.

B: 100 kVp, 15 cm water scatterer.

C: 90 kVp, 10 cm water scatterer.

Fig. 3 System response to varying contrast levels produced by several concentrations of Renografin-60. The water depth was 20 cm and the tube potential 120 kVp.

A: 10 percent concentration;

B: 25 percent, and

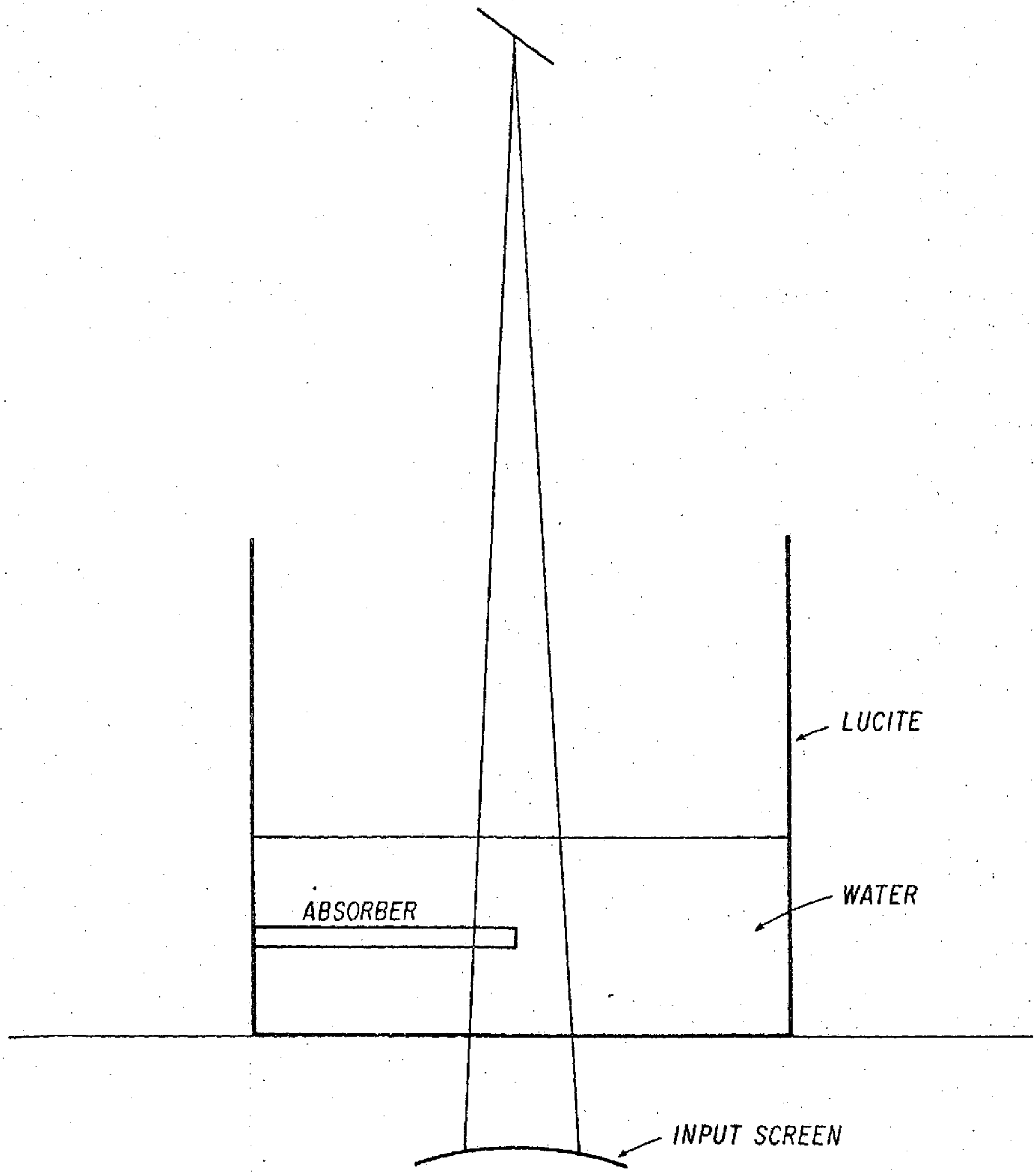
C: 50 percent.

Fig. 4 System response to varying contrast levels produced by air cavities when introduced into 20 cm of water using 120 kVp.

Fig. 5 System response to varying contrast levels produced by air cavities when introduced into 20 cm of water.

Curve A, is for 120 kVp (same data as used in Fig. 4), and

Curve B, is for 100 kVp.



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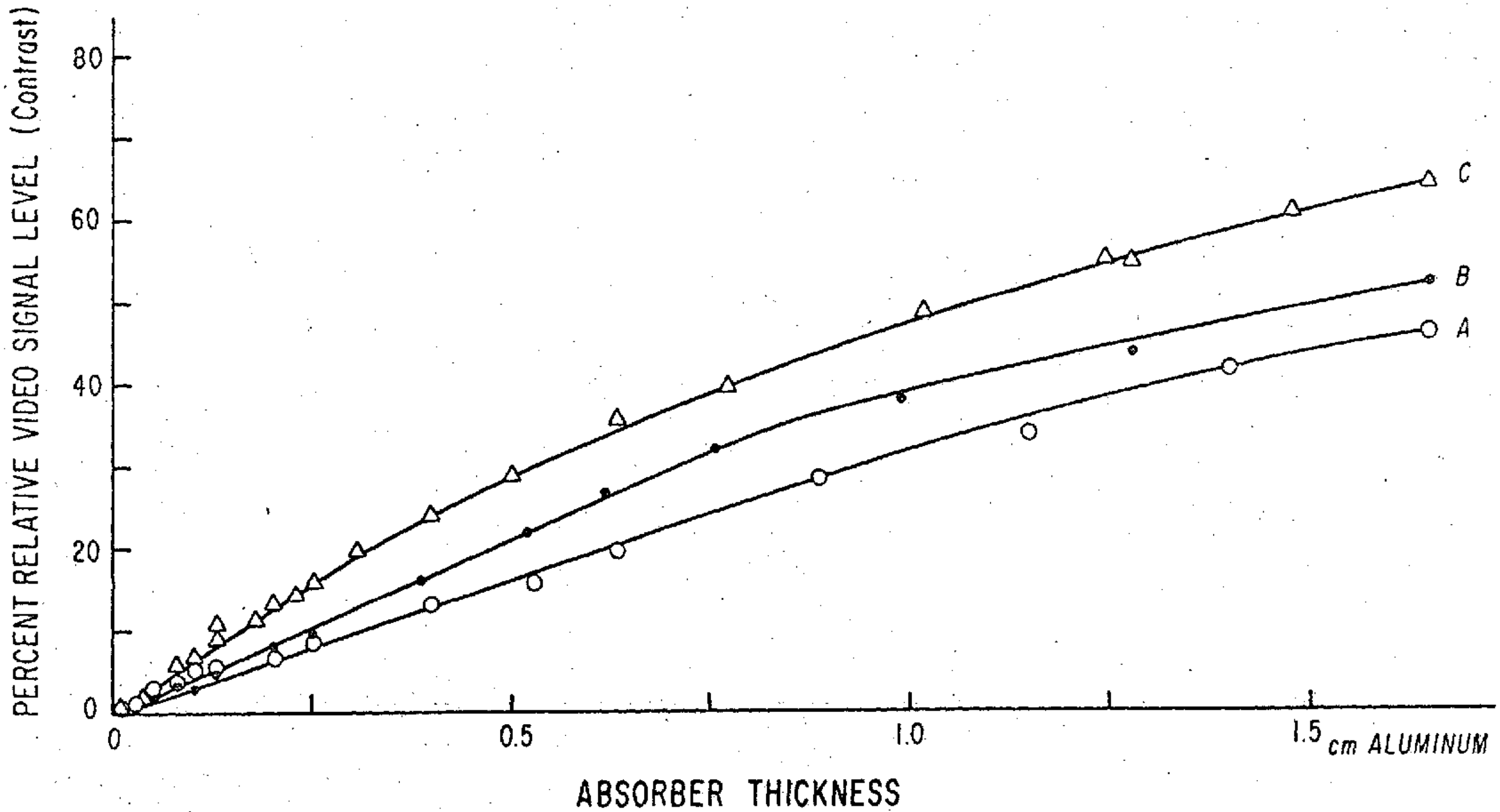

Fig. 2 System response to varying contrast levels produced by aluminum absorbers.
A: 120 kVp, 20 cm water scatterer. B: 100 kVp, 15 cm water scatterer. C: 90 kVp, 10 cm water scatterer.

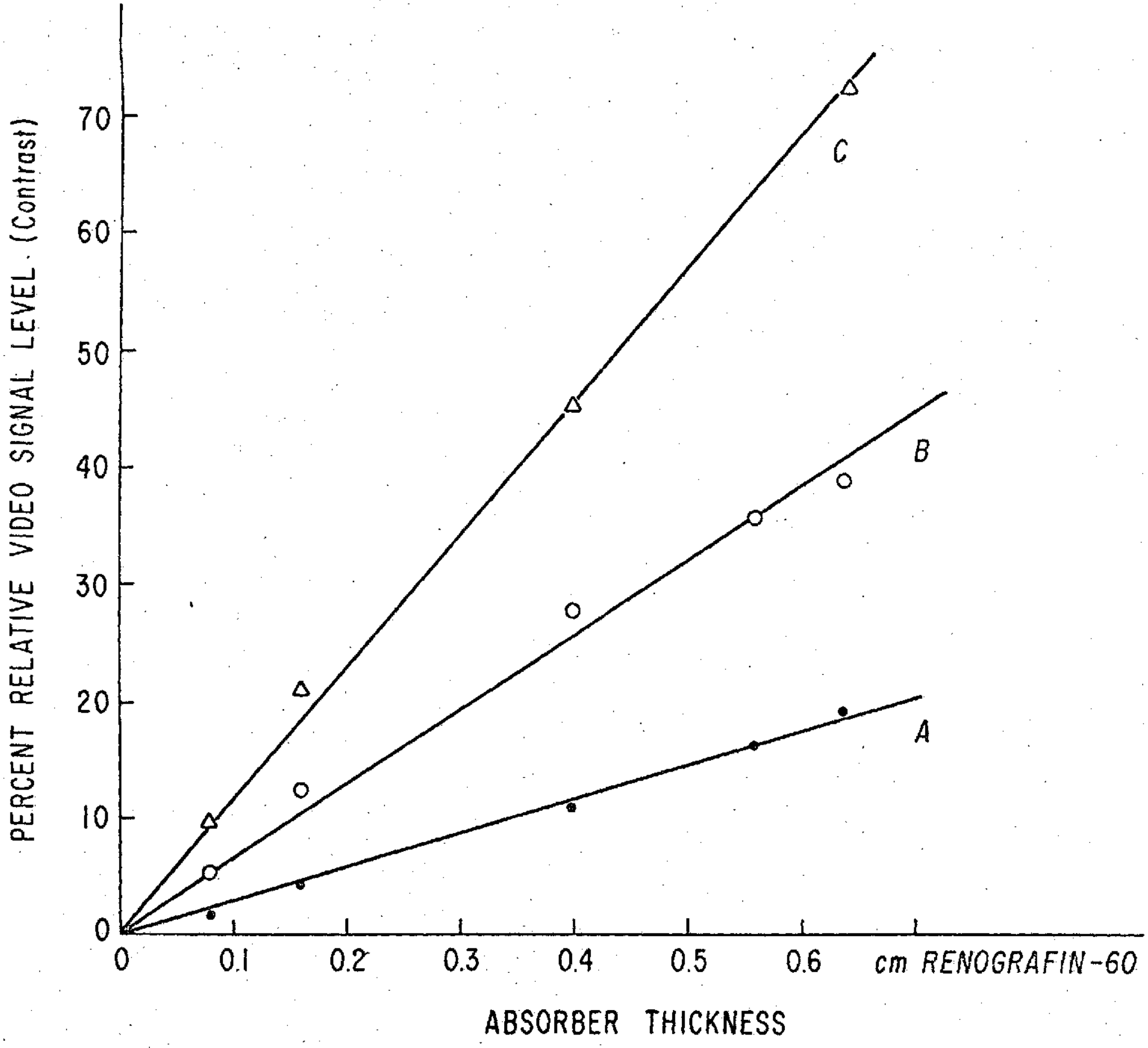

Fig. 3 System response to varying contrast levels produced by several concentrations of Renografin-60. The water depth was 20 cm and the tube potential 120 kVp. A: 10 percent concentration; B: 25 percent, and C: 50 percent.

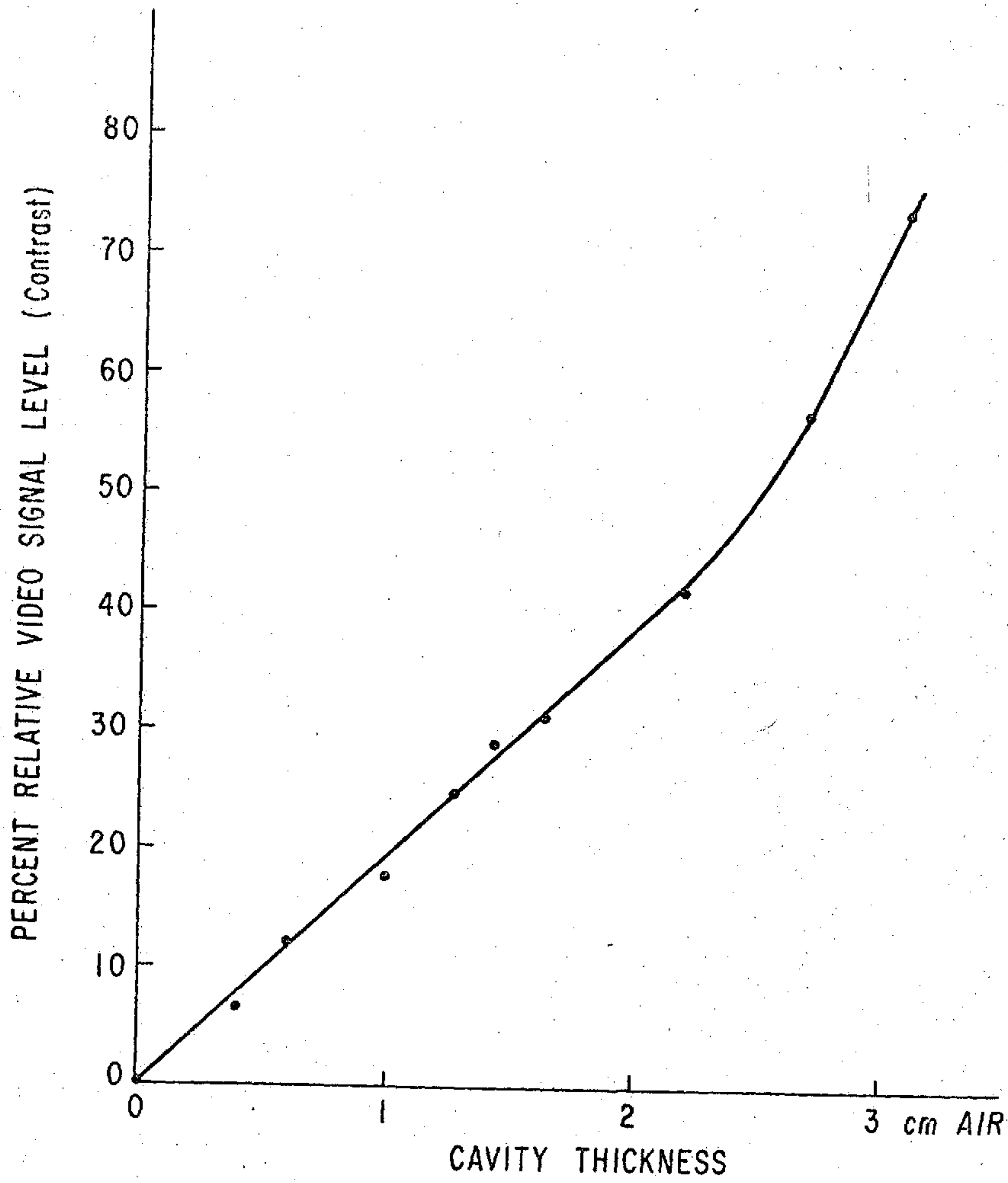

Fig. 4 System response to varying contrast levels produced by air cavities when introduced into 20 cm of water using 120 kVp.

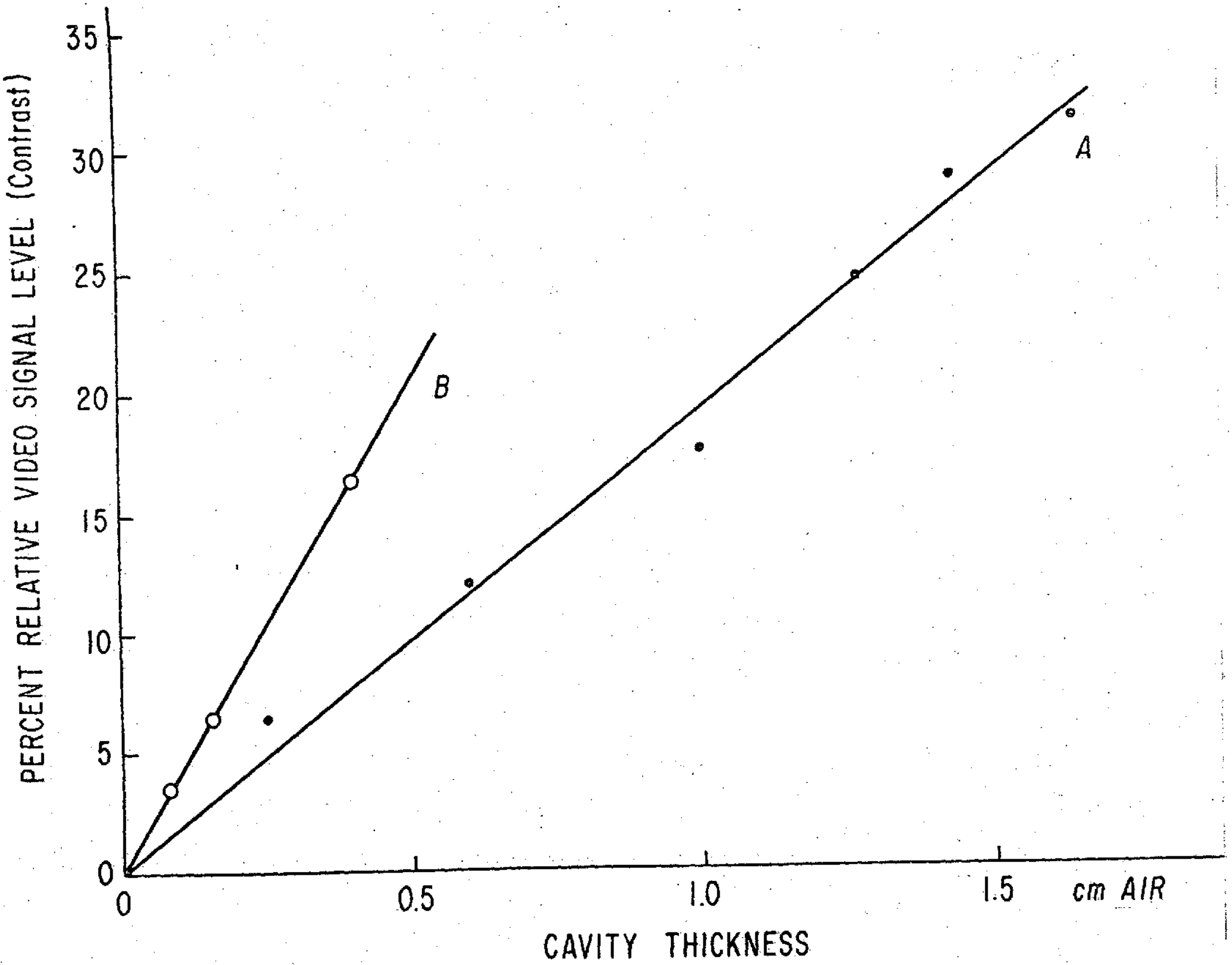

Fig. 5 System response to varying contrast levels produced by air cavities when introduced into 20 cm of water. Curve A, is for 120 kVp (same data as used in Fig. 4), and Curve B, is for 100 kVp.

TABLE I

MINIMUM DETECTABLE CONTRAST LEVELS (C_{min})

Material	Water Depth (cm)	Tube Potential (kVp)	Standard Deviation (percent)	Thickness of Material (mm) Corresponding to C_{min} at 2σ
Al	10	90	0.849	0.6
Al	15	100	0.465	0.5
Al	20	120	0.723	0.6
10%, Renografin-60	20	120	1.10	0.8
25%, Renografin-60	20	120	0.578	0.2
50%, Renografin-60	20	120	0.828	0.1
Air	20	100	0.797	0.4
Air	20	120	0.802	0.9