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Abstracts of Papers Read at The Annual Meeting of The Society of Nuclear Medicine,

Southeastern Chapter, Durham, North Carolina, November 3-5, 1966

1. *"Tumor Uptake of ^{75}Se Methionine."* FRANCIS B. DE FRIESS, (Radiation Safety Office, University of North Carolina School of Medicine, Chapel Hill, North Carolina)

Experiments have been conducted giving ^{75}Se Methionine to rabbits with and without Shope Papilloma. The distribution of the ^{75}Se Methionine and the relative tissue concentrations were studied over a period of a few hours to 100 days. The ^{75}Se Methionine was also given to terminal cancer patients and their distribution and uptake studied by scanning and at necropsy.

2. *"Radiation Exposures at a Typical University."* FRANCIS B. DE FRIESS, (Radiation Safety Office, University of North Carolina School of Medicine, Chapel Hill, North Carolina)

The Radiation Safety Office has compiled the quantity of radioactive materials used and then recorded radiation exposure of the technicians and staff handling this material, as well as the radiation exposures of the technicians and staff in the associated teaching hospital. The author would suggest that these indicate present standards are reasonable and in most instances performance is much more conservative than present standards.

3. *"Assay of Radionuclides in the Nuclear Medicine Laboratory."* EDWARD M. SMITH, (Division of Nuclear Medicine, University of Miami School of Medicine, Miami, Florida)

All radionuclides should be assayed before they are administered to humans. The importance of assaying radionuclides in the nuclear medicine laboratory has increased with the steady rise in the use of radionuclide generators and short-lived radionuclides. The available simple secondary assay methods include the well-ion chamber, the G. M. tube and gamma-ray spectroscopy. The manner in which each of these techniques should be used as well as their advantages and disadvantages will be discussed. Only gamma-ray spectroscopy may be used to determine radionuclidic purity.

The factors which may lead to errors in the assay of radionuclides will be considered. These include source-detector geometry, sample volume, photon attenuation by the sample container and by the sample itself, and high activity samples. The calculation of photon yields from decay scheme data as well as uncertainties in the decay scheme may lead to variability between laboratories.

A short discussion of the methods of determining the radiochemical purity of radiopharmaceuticals was included. The importance of evaluating the radiochemical purity of radiopharmaceuticals is increasing in the nuclear medicine laboratory as more and more compounds are being synthesized for human use from short-lived radionuclides.

4. *"A Multifunction Digital Scintillation Scanning System with a Clinical Example."*[1] EDWARD M. SMITH, H. G. MATTHEWS, JR., AND DAVID G. ANDERSON, (Division of Nuclear Medicine, University of Miami School of Medicine, Miami, Florida; Hamner Electronics Company, Inc., a subsidiary of the Harshaw Chemical Co.; and Hospital for Special Surgery, affiliated with the New York Hospital-Cornell University Medical College)

This installation consists of a mechanical scanner, nuclear instrumentation, programmer (data acquisition and control instrumentation), and an overhead x-ray unit. The two opposing 5″ × 3″ Na(Tl) plus 5″ × 2″ NaI detectors may be operated in a step scan made or continuous scan made at scan speeds up to 400 inches per minute covering a scan area of 30 inches by 76 inches. The signals from the detectors are processed by A.E.C. Standard Instrument Modules as independent outputs, as a mixed output, as a coincidence output, or in some combination of these. Two A to D converters monitor the scan position coordinates. The programmer provides the functions of: (1) coordinating the mechanical scanner with the data accumulation system; (2) storing significant data; (3) detecting selected position coordinates; (4) serializing stored data and (5) providing variable format interfacing with standard teletype-writing equipment.

In the step scan mode, data is accumulated at each step position, transferred to the programmer memory and read out after the scanner has been instructed to advance to its next step.

In the continuation scan mode, front panel switches on the programmer provide a selection of up to six "signal lines" parallel to the long axis of the patient; the two outside switches indicate scan extremes. Each data channel accumulates counts as the scanner traverses the patient, and transfers its accumulated data to the memory of the programmer whenever a signal line is crossed; simultaneously the data channels are zeroed and restarted.

In either scan mode, the switches on the programmer may be set to detect up to four discrete points or anatomical landmarks. Whenever the scanner passes one of these points, an identifying letter is stored for a subsequent readout.

The primary clinical study to date has been directed at studying the pattern of distribution of strontium-85 in osteoarthritis of the knee.

5. *"Evaluation of a Clinical Body Counter."*[2] EDWARD M. SMITH, (Division of Nuclear Medicine, University of Miami School of Medicine, Miami, Florida)

A clinical whole body counter has been designed, with simplicity of operation in mind, which utilizes the shadow shield technique as described by Morris (*J. Nuc. Med.*, 6:481. 1965). The shadow shield consists of two lead troughs, each weighing approximately 5700 pounds; one suspended from the ceiling, the other mounted on the floor. Each trough contains four 3″ × 2″ NaI(Tl) crystals. The patient lies on a stretcher, which is placed over the lower trough. The cost of the entire system including installation (which should be compatible with most existing buildings that have been recently constructed), electronics and detectors is approximately $25,000.

The four crystals in each trough are distributed in such a manner that at any location within the standard-man phantom (ORINS-35, April, 1960) filled with water a point or distributed photon source with an energy greater than 120 keV will yield the same response

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[1]Work performed at The Hospital for Special Surgery Cornell University Medical Center, New York City. Financial support for this work was obtained from U.S. P.H.S. Grant No. AM 09982-01.

[2]Work performed at The Hospital for Special Surgery, Cornell University Medical Center, New York City. Financial support for this work was obtained from U. S. Public Health Service Grant No. AM 09982-01.

within ± 10%. Excellent agreement has been obtained between total body retention of strontium-85 in a patient as measured by the whole body counter and as determined by excretion studies. One tenth of a microcurie of strontium-85 can be measured in a patient in 30 minutes with 3% precision.

The effect of that source distribution and scattering medium have on the shape of the gamma-ray spectrum was discussed with respect to the sensitivity and position response of the whole body counter. Source distribution and scattering medium will influence the energy interval, which should be monitored by the pulse height analyzer. The effect crystal size has on the sensitivity and position response of a whole body counter of this design was also presented.

6. *"Determination of Glomerular Filtration Rate by External Monitoring of Chromium-51 Labeled Inulin."* ALBERT E. JOHNSON, AND FRANK GOLLAN, (Veterans Administration Hospital and University of Miami School of Medicine, Coral Gables, Florida)

We have prepared a ^{51}Cr-labeled inulin which is stable in the laboratory as well as *in vivo*. There is no unbound radioactivity for which to correct and, in the dog, simultaneous glomerular filtration rate studies using stable and radioactive inulin with urine and plasma sampling give identical results.

In this study, dogs were given a single i.v. injection of 50 μC ^{51}Cr-labeled inulin. One hour later, scintillation detectors were placed over the heart and kidneys, and the rate of disappearance of radioactivity was recorded for a 15-minute period. A plasma sample was taken at the midpoint of the curve for calculation of absolute values. The rates of disappearance of radioactivity over the heart and kidneys were plotted semilogarithmically. From the heart concentration curve and the midpoint plasma sample in CPM/ml, we calculated the volume of distribution from which the ^{51}Cr inulin was being cleared by dividing the CPM injected by the CPM at the zero time intercept. Total ^{51}Cr inulin clearance rate was then found by multiplying this volume of distribution with the slope of the heart concentration curve. Differential glomerular filtration rate was then readily calculated by multiplying this volume of distribution with the slope of the disappearance rate of radioactivity obtained over each kidney.

Comparing this method of external monitoring with the simultaneous measurement of glomerular filtration rate using the conventional technique of plasma and differentially catheterized urine samples, we found complete agreement and a correlation coefficient of 1.0.

The entire procedure can be done using a single detector by first establishing the heart concentration curve followed by the curves of each of the kidneys. This procedure is made possible by the fact that the slopes are constant and the radioactivity is sufficient for measurement for over two hours. Thus, the determinations can be repeated without additional injection and require another 15 minutes of recording time.

The substitution of external monitoring of each kidney for differential catheterization of both ureters and the substitution of external monitoring of heart or forearm for repeated blood sampling offer advantages in time, accuracy, convenience and safety, which are unobtainable with the chemical inulin procedures.

7. *"Calibration Problems in the Measurement of Radionuclides."*[1] D. A. Ross, (Oak Ridge National Laboratory, Oak Ridge, Tennessee)

In the clinical laboratory radionuclides are measured *via* a chain of proportionalities: disintegration rate varies as the amount of nuclide present; emitted radiation varies as the disintegration rate; detector response varies as the radiation flux (photons per second per square centimeter); and so forth. But the photons caught by the detector may be an unknown

[1]Research sponsored by the U. S. Atomic Energy Commission, under contract with Union Carbide Corporation.

fraction of the total emitted; moreover, not every photon reaching the detector gets counted. Hence it is necessity to *counting by comparison*—to compare the unknown with a known standard. A number of conditions must be controlled, however, if the comparison is to be valid: geometry, absorption, scattering, size of source, crystal transparency, pulse-height selection, etc. The practical problems that arise were discussed and illustrated with examples.

8. *"Positive Brain Scans Due to Lesions of the Skull."* C. Douglas Maynard[1], T. G. Hanner, Jr.[2], and R. L. Witcofski, (Department of Radiology, Bowman Gray School of Medicine, Winston-Salem, North Carolina)

A wide variety of skull lesions causing positive brain scans have been encountered while performing over 2,000 scans utilizing ^{99m}Tc pertechnetate. These included hyperostosis frontalis, cavernous hemangioma, metastatic lesions, multiple myeloma, fibrous dysplasia, burr holes, and craniectomy defects. Positive brain scans related to craniectomy defects were elaborated upon. The importance of correlating x-ray findings with scans was emphasized.

9. *"Distribution of New Radioactive Disulfonamido Derivatives in Rats with Transplanted Walker Carcinosarcoma."* Danuta Malejka; Introduced by F. E. Ray, (Pharmaceutical Chemistry Research Laboratory, College of Pharmacy, University of Florida, Gainesville, Florida)

Five new radioactive compounds: N,N′-bis(carbamyl)-2,7-fluorene[^{35}S]disulphonamide, III, N,N′-bis(p-tolylsulphonyl-carbamyl-n-butyl)-2,7-fluorene[^{35}S]disulphonamide, IV, N,N′-bis(4-carboxy-phenyl)-2,7-fluorene[^{35}S]disulphonamide, V, N,N′-bis(5(6)-nitro-benzimidazolyl)-2,7-fluorene[^{35}S]disulphonamide, VI, and N,N′-bis(6(2,4-dimethoxy-pyrimidyl))-2,7-fluorene[^{35}S]disulphonamide, VII, were synthesized, and their tissue distribution six hours after a single intravenous injection to tumour-bearing (Walker carcinosarcoma) and tumour-free Wistar rats was studied. The data obtained were discussed in relation to the bis-thiazole (Compound I) and bis-guanidyl (Compound II) derivatives examined previously (Malejka, 1965). This similarity of chemical structure of the substituents at 2,7-disulphonamido-fluorene draws a line of common factors in the behavior of Compounds II and III, Compounds IV and VI, and Compounds I and VII. The distribution data for these paired compounds are similar. Compounds II and III are not present in tumour. The concentration in tumour of Compounds IV and VI is very similar and reveals favorable ratios for red blood cells, liver, lungs (statistically significant), and for plasma, leg muscle and carcass for both compounds, and also for spleen and kidneys for Compound IV. The highest concentration in tumor (77 μg. per g. tissue) is achieved with Compound VII and this value gives favorable ratios for red blood cells, plasma, lungs, leg muscle and carcass (all statistically significant).

The present studies have shown an impaired elimination of fluorene disulphonamides in presence of tumour with Compounds III, V and VII. Four of the examined compounds (IV, V, VI and VII) tend to localize in the liver and spleen of tumour-free rats to a greater extent than in tumour-bearers, thus showing a weakened phagocytic function of the reticulo-endothelial system in the presence of tumour.

10. *"The Effect of Hepatectomy on the Disappearance and Reappearance of ^{75}Se-Labeled Methionine."* Carl Selin and Harvey L. Cromroy, (Departments of Pathology and Radiology, University of Florida, Gainesville, Florida)

Following intravenous injection ^{75}Se-labeled methionine has been reported to disappear rapidly from the blood reaching its lowest concentration in 30 minutes and then returning to 75% of the 2 minute concentration in 4 hours (Oldendorf, *J. Nuc. Med.* 4:231, 1963). Using

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[1]James Picker Foundation Scholar in Radiological Research

[2]American Cancer Clinical Fellow

25 white rats (SDD strain) it was possible to demonstrate this same phenomenon. The curve obtained is similar to that described by Oldendorf. It was found that when the medial, right and left lateral lobes of the liver (approximately 80%) were removed prior to injection of the isotope, the fall in blood concentration of ^{75}Se was roughly exponential. When hepatectomy was performed 30 minutes after injection i.e., at the time of lowest blood concentration, reappearance of the isotope was markedly decreased and in rough proportion to the amount of liver remaining. The liver appears to be responsible for the reappearance of ^{75}Se-labeled methionine. Twenty-four hours after injection, serum protein distribution of ^{75}Se methionine was found to be fairly uniform as demonstrated by paper electrophoresis.

11. *"A Relationship Between Interphase Chromosome Volume and Radiation Sensitivity in Mammalian Species."* ALAN PORTER, ALASTAIR H. BURNS, AND HARVEY L. CROMROY, (Departments of Radiology and Anatomy, University of Florida, Gainesville, Florida)

Previous work by Sparrow, Schairer and Sparrow (*Science* **141**:163, 1963) indicated a linear relationship between the interphase chromosome volume of certain plant species and $LD_{50/30}$ days as a result of gamma and x-radiation exposure. This research is concerned with determining the relationship in mammalian species. The species studied were mouse, guinea pig, monkey, man, cat, dog, and several strains of rats. The lining endothelium of the intestine was the tissue selected for measurement, since it is known to be radiosensitive and shows minimal size variation between cells in a species. Two hundred cells were measured for each species. Volume calculations were made with a digital computer assuming the nucleus to be both ellipsoid and spherical in shape. This method provides the statistical validity required for any generality to be made. From the observations, the slope of the curve does not agree with the slope which Sparrow obtained for plants. An explanation of the difference between Sparrow's work and our own will be given.

12. *"Radiation Effect on Rat Thymus Nuclei."* DANIEL H. ZIMMERMAN and HARVEY L. CROMROY, (Department of Radiology, University of Florida, Gainesville, Florida)

This research was aimed at demonstrating the effects of ionizing radiation on nuclear oxidative phosphorylation. Rat thymocyte nuclei from male SDD rats, five to six weeks of age, were studied for the effect of x-irradiation. The rats received doses of 100 *R* and 200 *R* and were sacrificed one hour after exposure to ionizing radiation. The experiments did not confirm previous research which reported that there was a decrease in the irradiated thymocyte nuclei's ability to produce acid labile phosphate. It was shown that these nuclei formed orthophosphate during an incubation period of 30 minutes at 0°C. The implications of the orthophosphate production will be discussed and possible mechanisms outlined.

13. *"The Use of the Beta Radiation in Suppressing Specific Immunologic Response in the Cornea."* DENNIS R. MORRISON AND HARVEY L. CROMROY, (Department of Radiology, University of Florida, Gainesville, Florida)

Heterozygous, interlamellar corneal transplants have been used to produce a unique, localized immunological response. The avascular property of the cornea makes the immune reaction dependent on some form of migration of the antibodies to the isolated site or on local production at the site. This response is characterized by a neovascularization, which originates at the limbis and progresses inward to the implant, and the eventual appearance of a dense white precipitate described as an "immune ring."

Extensive experimentation has been carried out in an attempt to suppress this immune response with topical application of certain steroids. The success of these attempts has prompted the use of beta radiation to elicit the same type of suppression. The experimental animals were Dutch-pigmented female rabbits with pig cornea serving as the heterologous donor. Se-

quential surface doses of 5,000 and 10,000 roentgen equivalent beta radiation was administered from a specially constructed ^{90}Sr ophthalmic applicator at various times after implantation. The inhibition of neovascularization and correlated cellular changes were evaluated as to their importance in the development of the immunologic response.

14. *"Comparison of ^{99m}Tc and ^{125}I Thyroid Scans."* JOHN L. SCHULTZ, CAPT. USAF, T. G. HANNER, R. L. WITCOFSKI, AND C. DOUGLAS MAYNARD, (Department of Radiology, Bowman Gray School of Medicine, Winston-Salem, North Carolina)

Technetium-99m pertechnetate has been shown to be concentrated in the thyroid, among other places, after oral or intravenous administration; it behaves in the normal gland as does iodide in the gland blocked with methimazole. Technetium-99m would appear to have certain advantages over ^{125}I in thyroid scanning: lower radiation dose to the thyroid; elimination of the 24-hour delay necessary with ^{125}I; shorter physical half-life; and reduced cost.

Over fifty patients, all of whom were suspected of having thyroid disease and most of whom had solitary nodules, were scanned with both ^{99m}Tc and iodine-125.

It was concluded that at present ^{125}I appears to be the better of the two isotopes in delineating "cold" nodules; however, ^{99m}Tc scans are satisfactory in most instances. In areas of hyperfunction it would appear that the ^{99m}Tc scans are better.

15. *"Rhenium-188 as a Possible Diagnostic Agent."* R. L. HAYES and J. J. RAFTER, (Medical Division, Oak Ridge Institute of Nuclear Studies, an operating unit of Oak Ridge Associated Universities, Inc., Oak Ridge, Tennessee, under contract with the United States Atomic Energy Commission)

Although ^{99m}Tc is extremely useful in diagnostic procedures, the ^{99m}Tc generator system has only a short useful life (parent ^{99}Mo $t_{1/2}$ = 28d). Rhenium is chemically very similar to technetium. Short-lived ^{188}Re ($t_{1/2}$ = 17 h) can be obtained from a generator system (developed at the Oak Ridge National Laboratory) employing parent wolfram-188 ($t_{1/2}$ = 69d). The principal photon emitted in the decay of ^{188}Re has an energy of 155 keV. Although ^{188} Re has a low useful photon emission and some associated high-energy radiation, the long useful life of the ^{188}Re generator system makes ^{188}Re attractive. The distribution and excretion of ^{188}Re in the perrhenate form has been studied in various animals. The tissue distribution was found to be similar to that of ^{99m}Tc with concentration in the thyroid, stomach, and salivary glands. The excretion was mainly via the urine in contrast to that of Technetium-99m. A sulfur colloid of ^{188}Re has been prepared and investigated in the rabbit. Rhenium-188 appears to have possible diagnostic applications and is in some respects superior to ^{99m}Tc, although the calculated radiation dose to various organs is higher.

16. *"Uptake of ^{99m}Tc in the Choroid Plexus."* R. L. WITCOFSKI, C. D. MAYNARD, R. JANEWAY AND E. K. BEARDEN, (Departments of Radiology and Neurology, Bowman Gray School of Medicine, Winston-Salem, North Carolina)

During routine brain scanning with ^{99m}Tc pertechnetate, a small percentage of patients had concentration of the radionuclide in the region of the choroid plexus. The intensity of the scan pattern varied from minimal activity to large concentrations which were initially misinterpreted as lesions. Repeat ^{197}Hg chlormerodrin scans on these patients showed no activity in this region. Repeat ^{99m}Tc brain scans after oral administration of 200 1 mg potassium perchlorate demonstrated nearly complete blockage of this uptake. Since the uptake of the material could be blocked with perchlorate, it would appear that an active secretory mechanism was involved. Animal studies were undertaken to determine if it was indeed the choroid plexus which we had visualized. These results were reported in detail.

17. *"A Technicians' View of the T-3 Test."* NORMA C. GREENWOOD, (Chief Radioisotope Technician, Department of Radiology, Bowman Gray School of Medicine, Winston-Salem, N. C.)

The three most widely used T-3 tests were compared with respect to technical factors, reproducibility, time involved, and cost. Such factors as shelf life, control of incubation time, total time, and actual technician time were considered. Reproducibility was determined by utilizing pooled human serum.

18. *"Studies of Myocardial Blood Flow with ^{133}Xenon."* RALPH J. GORTEN and STEVEN T. LEVY, (Radioisotope Service, Veterans Administration Hospital and the Departments of Radiology and Medicine, Duke University Medical Center, Durham, North Carolina)

The ^{133}Xenon clearance technique of Lassen for Skeletal muscle blood flow was adapted for measurements of myocardial capillary flow in experimental animals. Using direct injections of Xenon-133 in saline solution, wafer scintillation crystal detectors, and the formulas derived by Kety, flow was calculated in ml/min/100 grams of myocardium. Prior to induced changes, flow was measured on 11 occasions with an average of 100 ml/min/100 g, (range 48-158).

During transient right coronary artery occlusion, the clearance slope and capillary flow dramatically decreased to zero in the antero-lateral portion of the right ventricle. In portions of the right ventricle closer to the anterior descending branch of the left coronary artery, flow decreased to varying degrees depending on the location. On release after 20-30 sec. occlusion, reactive hyperemia was observed in all regions supplied by the right coronary artery. In 11 studies, this ranged from 5 to 175% above preocclusion baseline figures.

Stimulation of the right vagus nerve caused a diminution of capillary blood flow in addition to the expected bradycardia. When this was combined with occlusion of the right coronary artery, flow in marginal regions where the blood supply was only partly reduced was decreased further by vagal stimulation. In addition to bradycardia, there was also a significant drop in mean aortic pressure.

Stimulation of the right cervical sympathetic trunk was accompanied by an augmentation of capillary flow, a more rapid heart beat, and a higher mean aortic pressure. However, when superimposed on coronary occlusion, areas of reduced blood supply suffered further decreases in flow. Cardiac rate and aortic pressure increased, but not to the same levels as when coronary arteries were patent.

In summary, the Xenon-133 clearance technique provides a valuable means for studying nutrient blood flow in specific regions of myocardium. The indicator diffuses rapidly enough to reveal that reactive hyperemia does occur in the heart. In experiments with vagal or sympathetic stimulation and right coronary arterial occlusion, the surprising findings were that enhanced vagal activity caused a decreased and augmented sympathetic activity and an increase in flow, but that during arterial occlusion both forms of autonomic nervous system activity diminish significantly the flow in regions of marginal blood supply.

19. *"ORNL Isotopes Development Center's Cooperative Program in New Medical Radionuclides.*[1]" HOMER B. HUPF, (Isotopes Development Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee).

Advances in the field of nuclear medicine have been achieved through the use of recently available radioisotope preparations, such as ^{67}Cu, ^{131}Cs, ^{84}Rb, ^{33}P, ^{197}Hg, and Zinc-69m. The Isotopes Development Center of Oak Ridge National Laboratory contributes to the medical research program by developing the production technology and by providing research quantities of previously unavailable radio-nuclides to medical and biological investi-

[1]Research sponsored by the U. S. Atomic Energy Commission under contract with the Union Carbide Corporation.

gators. The production technology for two such radionuclides, ^{123}I and ^{69m}Zn, is discussed in this paper.

Iodine-123 ($T_{1/2}$ = 13 hr; 0.159 MeV gamma) suitable for diagnostic scanning has been prepared in the ORNL 86-Inch Cyclotron by proton bombardment of isotopically enriched tellurium-123. Target material enriched to ~80% ^{123}Te provides an ^{123}I product containing less than 1% each of the radionuclides, ^{124}I (4.2 d) and ^{126}I (13 d). The iodine is separated completely from the tellurium by distillation, as indicated by gamma-ray spectrometry. The production rate averaged 88 mC per hour of proton beam at 185 μa and 95% of the target material was recovered, suitable for reuse.

Several medical investigators evaluated samples of experimental ^{123}I product and reported that thyroid scans using ^{123}I are comparable to those obtained with ^{131}I and result in a great reduction in radiation dose to the patient. Studies by one of the investigators are in progress to perfect a "depth perception" technique by double scanning the 0.159 MeV gamma ray and the 0.027 MeV tellurium x-ray.

Zinc-69m ($T_{1/2}$ = 14 hr; 0.440 meV gamma) in equilibrium with its isomeric transition product ^{69}Zn ($T_{1/2}$ = 55 min; 0.91 Mev β^-) has been prepared for medical and biological studies in cooperative programs with several medical investigators.

A concentration of 2 mC of ^{69m}Zn per mg of zinc was obtained by the $^{68}Zn(n,\gamma)^{69m,69}Zn$ reaction in a high thermal flux region of the Oak Ridge Research Reactor (ORR). The ^{69m}Zn was used by medical investigators to determine the site of zinc uptake in the rat prostate. Since extension of these studies to humans would require ^{69m}Zn activity of a higher isotopic abundance (carrier free), the $^{69}Ga(n,p)^{69m}Zn$ reaction was studied. Millicurie amounts of carrier-free ^{69m}Zn were produced using natural Ga_2O_3 targets in a high fast neutron flux region of the ORR. Separation of the ^{69m}Zn from the gallium target is accomplished by solvent extraction methods using methyl isobutyl ketone or by ion exchange using Bio-Rad AG-1 in the chloride form.

20. *"A New Photorecording Method for Moving-Detector Scanners."*[1] C. C. HARRIS, M. M. SATTERFIELD, G. R. DYER, AND P. R. BELL, Oak Ridge National Laboratory, Oak Ridge, Tennessee).

It has been recognized that scan photorecording defects, such as the discreteness of black spots and large open streaks because of spacing, hinder visual interpretation. Data-blended photorecordings represent a method of removing such defects, but this method causes loss of detail. We have been experimenting with scan recording methods that present all of the data, but yet have expanded dynamic range. The mechanical multistylus dot tapper, or "multidotter," reported in 1962 was a first attempt;[2] this device is now used widely in Japan. We also reported at that time the concept of a photographic version of the multidotter which should be considerably better than the mechanical device.

Some experimental models of the photographic multidotter were made and one was installed on an Ohio-Nuclear scanner at the ORINS Medical Division. Though chiefly designed to produce records for use with the rescanner,[2] the device has been producing scan records that seem to yield improved results in ordinary visual interpretation; this is especially true with high counting rates. (The same principle has been used with a cathode ray oscilloscope and a Polaroid camera as a recording system, giving a small, but good, scan record within a few seconds at the end of a scan.)

The records produced by this photo-multidotter tend to look more like pictures from the Anger scintillation camera, except that they are full-size, and are capable of showing the good definition which can be obtained with moving-detector scanners.

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[1]Research sponsored by the U. S. Atomic Energy Commission under contract with Union Carbide Corporation.

[2]Progress in Medical Radioisotope Scanning, USAEC TID 7673, 1963.

21. *"Moving-Detector Scanners and Stationary Imaging Devices."*[1] C. C. Harris, M. M. Satterfield, D. A. Ross and P. R. Bell, (Oak Ridge National Laboratory, Oak Ridge, Tennessee)

We have made a comparison between moving-detector scanners and a stationary device by calculation and by limited experimentation. A conclusion suggested by the calculations and verified by the experiments is that moving-detector scanners and stationary devices are basically quite similar their performance is described by essentially the same equations; however, per unit of detector area, the moving-head scanner is somewhat superior. Its advantage is ascribable mainly to the higher detection efficiency of its thicker crystal, and to inherent limitations in resolution of such devices as the multi-aperture scintillaton camera. Stated another way, the concluson is that if a moving-head machine can move rapidly enough with a detection system of sufficient area, it will acquire more counts—with better resolution—than a stationary device in the same time.

For a moving-detector scanner to compete *directly* with a stationary device, it must have the same gross detector area divided by any intrinsic peak efficiency advantage it may have. For a stationary device to compete with a moving-detector scanner having the same gross detector area-efficiency product, the actual detector area must be as large as the target; otherwise a second view to complete the picture will be required.

The study also shows that the *positron* camera is in principle, superior to either moving-detector or existing single-sided stationary devices because in making use of annihilation collimation, it avoids losses due to the inherently poor geometrical efficiency of absorption collimation.

22. *"Observations on the "Blood Cerebral Spinal Fluid Barrier": Functional Estimates with Bi-Directional Isotope Techniques."* Richard Janeway, (Department of Neurology, Bowman Gray School of Medicine, Winston-Salem, North Carolina)

The origin and fate of CSF and the function of the blood-CSF-barrier remain enigmatic because of conflicting information derived from anatomic studies, hydrodynamic investigations, and by both isotopic and non-isotopic tracer techniques. Some of the confuson has arisen because investigators have failed to take into consideration the factors of comparative compartment size, non-uniform mixing in the CSF compartment, and the inability to estimate rate functions by unidirectional experiments.

Concentration differences across the blood-CSF-barrier may exist in either direction and in some disease states in which generalized permeability disturbances are assumed to be operative, there may be selective alterations in the concentration of some components, while others remain normal. Since these concentration differences follow no constant relation to molecular size, it seems likely that enzymatic functions determining molecular transport have relatively more importance than the anatomic characteristics of the barrier. It is thus important to be able to make valid estimates of rate functions, rather than to obtain only information relative to the permeability of the membrane.

Dissimilar rates must be determined in opposite directions across a membrane in order to establish that any work is performed or that anything is formed in a compartment. This requires injection into both the central and peripheral compartment to determine physical transfer rates (a reflection of physiologic capability) and must be performed on matched experimental populations or be done at intervals in the same population. Specific activity versus time curves after injection of isotope into a single compartment of a mammillary system can demonstrate only that a semi-permeable membrane exists between the compartments and should not be interpreted as an estimate of work performance. When bi-directional techniques are used, comparisons of compartment size are immediately available. Comparison of rate

[1]Research sponsored by the U. S. Atomic Energy Commission under contract with Union Carbide Corporation.

measurements extrapolated to t_0 eliminates the constraints imposed by non-uniform mixing in relatively sluggish peripheral compartments such as CSF. Data was presented which illustrate these points.

23. *"Control Systems for an Isotope Scanner."*[1] W. E. Cook, C. E. Kramer, W. R. Baker, R. M. Heyssel, and A. B. Brill, (Vanderbilt University Hospital, Nashville, Tenn.)

Quantitative studies of isotope retention and distribution using low levels of radioisotopes in man have pointed to the desirability of combining a scanning system with a low level whole body counter. Modifications of the present whole body counter are being made which provide the detection sensitivity of the chair geometry while minimizing the effect of varying geometrical efficiency as translocation of the isotope occurs with the passage of time. Opposed 8" NaI crystals produce a longitudinal scan of programmable length and velocity from head to toe. In addition, with appropriate collimators, a rectilinear or profile scan can be produced where only photopeak counts are collected. By the use of a 4096 channel analyzer, as a buffer storage, digital information is acquired and stored in an appropriate matrix reflecting the distribution of a particuluar nuclide in the body.

The principle design problems involved fitting the equipment into the small space available (8′ × 6′), maintaining the low radioactive background in the room, excluding electrical noise from the system, providing a wide range of scan speeds and motions, allowing for the future computer control of the scanner, while providing a constant scan speed and accurate positional information as the large mass (4000 #) is moved back and forth across a patient.

A hydraulic system was selected because of its fast response, and low electrical noise, in preference to a d.c. motor drive system or an all digital system using pulse stepping motors. A discussion will be presented of the advantages and limitations of the various approaches to the mechanical layout of the scanner, the hydraulic driving mechanism, the feedback control system, and means of position indication. In addition, attention will be given to the optimization of system performance including the signal to noise ratio, and positional and velocity accuracy.

24. *"Biological Turnover and Whole-Body Counter Calibration of Cesium in Man."*[2] E. G. Stant, Jr., A. B. Brill, R. E. Johnston and R. M. Heyssel, (Vanderbilt University Hospital, Nashville, Tenn.)

The Vanderbilt whole-body counter (chair geometry) previously was calibrated for ^{137}Cs detection in man by determining the ^{40}K calibration factor with the use of potassium-42. The factor for ^{137}Cs was predicted on the basis of the energy-efficiency curve for our counter geometry. The recent availability of ^{132}Cs, a short-lived isotope whose decay scheme closely approximates that of ^{137}Cs, has made it possible to calibrate whole body counters for ^{137}Cs directly with minimal radiation exposure.

Cesium-132 was given orally to seven normal subjects. Body counts were obtained daily for several days and periodically for five weeks. Urinary excretion of radiocesium was determined for periods ranging from one to 16 days post-ingestion.

The nanocurie body burden of ^{132}Cs in each subject was calculated for each day, taking into account the measured urinary excretion of ^{132}Cs and fecal excretion estimated from the data of Rosoff, *et al.* The data-relating counts per minute from the subject to the calculated body burden suggested that cesium had not equilibrated by 24 hours. Regression analysis showed the "experimental" calibration factor (average value for days two to six) to be closely related to weight/height of the subject. A "theoretical" cesium calibration factor was

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[1]These studies were supported by the U.S. Atomic Energy Commission, Contract AT-(40-1)-2401.

[2]These studies were supported by the U.S. Atomic Energy Commission, Contract AT-(40-1)-2401.

derived from the potassium calibration factor determined on these same subjects and the energy-efficiency curve. This "theoretical" factor will be compared with the experimentally-determined factor.

The average biological half-life of cesium in these subjects was 65 days, ranging from 40 to 86 days. The amount of radiocesium excreted in the urine varied considerably between subjects (eg. 3.0 to 7.2% of original dose excreted in 24 hours.) However, the time course of the per cent excreted was similar for all subjects.

25. *"Internal Dosimetry of 75-Seleno Methionine."*[1] R. E. JOHNSTON, J. R. MATHER, A. B. BRILL AND R. M. HEYSSEL, (Vanderbilt University Hospital, Nashville, Tennessee)

The use of ^{75}Se-methionine for scanning the pancreas and parathyroid glands makes it important to obtain estimates of the radiation hazard from exposure to this compound to weigh against its usefulness in medical diagnostic procedures.

A determination of Γ, $\Sigma\gamma$, and $\bar{E}_\beta$ for ^{75}Se has been carried out using new experimental decay schemes. Biological distribution of ^{75}Se-methionine in rat organs was determined and the obtained curves were analyzed using a digital computer. The effect of the age at the time of injection of the seleno-methionine was investigated. The resulting curves for the per cent of injected dose per g of organ weight vs time show no major differences in shape, but they do indicate a greater uptake of radioactivity in the organs of younger rats.

The newly-derived physical constants for ^{75}Se and the biological data were used to evaluate the absorbed radiation dose. Due to the relationship between uptake of seleno-methionine and age, the absorbed radiation dose to the gonads of pre-pubertal rats was calculated to be of the order of 2½ times the dose to the gonads of post-pubertal rats. The potential importance of age in relation to metabolic activity and radionuclide concentration in evaluating the radiation hazard to biological systems will be discussed.

26. *"Digital Techniques for Radioisotope Scanning."*[2] W. J. O'NEILL, C. E. KRAMER, W. R. BAKER, and A. B. BRILL, (Vanderbilt University Hospital, Nashville, Tennessee)

A system for the acquisition of digital data from radioisotope scanning procedures in nuclear medicine has been in operation at Vanderbilt University for the past year. The system includes two scanners, 3″ Picker Magnascanner II, and an 8″ Ohio Nuclear Scanner coupled to a Packard 4096 multi-channel analyzer system. Positional information from the 3″ scanner is derived from optical shaft encoders, and from the 8″ scanner from helipot coupled to the drive mechanism of the detector. The 4096 channel analyzer permits a quantitative analysis of the performance of the scan system as a whole and by manipulation of the system, many of the components can be isolated and studied separately. Scanner speed characteristics, electronic stability and calibration, and performance of two different types of position indicators have been analyzed using this system.

The display of acquired data is available immediately on the face of the contour-volumetric unit. The angle from which the distribution can be viewed, the vertical and horizontal gain, as well as background cut off, contrast enhancement, and focusing can be varied at will, and a permanent photograph made of the image on the scope face.

Data are transmitted via cables to a remote digital computer system for further processing for special studies.

The results of early experience with this system will be presented.

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[1]These studies were supported by the U. S. Atomic Energy Commission Contract AT-(40-1)-2401, and by U. S. Public Health Service, Grants HE 07759-04(HEM) and 91-5336.

[2]These studies were supported by the U.S. Atomic Energy Commission, Contract AT-(40-1)-2401.

27. *"A Digital Data Acquisition and Analysis System for Radionuclide Scanning Collimators."*[1] R. J. KING, A. B. BRILL, P. H. KING, and C. E. KRAMER, (Vanderbilt University Hospital, Nashville, Tennessee)

A major emphasis of our program is directed toward the optimization of a clinical radionuclide scanning system through digital data acquisition and processing techniques.

The work on collimator evaluation has been prompted by a need for qualitative and quantitative descriptors of existing collimators for use in data analysis. Furthermore, we are attempting to obtain transformations between response profiles generated by different source geometrics. Collimator response data as a function of radionuclide, scattering media, subtended solid angle and source geometry have been collected for this purpose, and also to provide experience which may be of value in collimator design.

In order to obtain accurate quantitative data, we have utilized an automatic special-purpose plotter transport mechanism designed for radiotherapy depth dose studies, which has been interfaced to a digital data acquisition system.

The special purpose "isodose scanner" has been modified to move various types of sources in front of the collimator face in a rectilinear raster. The detector signal and positional information are addressed through an analog to digital converter and binary counter to a 4096 word buffer computer memory. The buffer memory is dumped onto punched cards and the data processed in a digital computer, which provides isoresponse contours. Point, line and plane source responses curves and their modulation transfer functions will be presented for several collimators which are in common use.

28. *"Computer Applications in Nuclear Medicine."*[2] P. H. KING, A. B. BRILL, R. J. KING, (Vanderbilt University Hospital, Nashville, Tenn.)

The acquisition of digital radioisotope scan data requires the utilization of digital computers for the analysis of results. Computer techniques are being developed in our laboratory for the analysis of these data and for the evaluation of the performance of equipment used for these procedures.

This paper describes several computer programs presently being used and under development. The following programs will be described:

(1) A collimator evaluation program, which provides contour plots showing the isoresponse profiles of a collimator to experimental source distributions.

(2) A contour plotting program, similar to the collimator response analysis, for use in patient brain scan presentation. Nonlinear scaling, data smoothing, background subtraction and isotope decay correction routines are added to enhance data presentation.

(3) A section scan analysis program, to obtain contour plots of radionuclide distributions from planar scans about the patient. This analysis will be applied to brain scans initially, and line scans being taken as the patient is rotated through 360° by 10° increments. A single crystal geometry is used. The method is similar to that described by Kuhl and co-workers, except that the depth response of the collimator is used in the analysis.

(4) A spectrum stripping program, using multiple regression analysis to determine radionuclide concentrations in multi-component mixtures. This program contains a subroutine to compensate for sum peaks in the experimentally-obtained spectra.

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[1]These studies were supported by the U. S. Atomic Energy Commission Contract AT-(40-1)-2401.

[2]These studies were supported by the U.S. Atomic Energy Commission, Contract AT-(40-1)-2401.

29. *"A Computer Controlled Information Retrieval System for an Individual Investigator."*[1] W. E. Cook and A. B. Brill, (Vanderbilt University Hospital, Nashville, Tenn.)

The investigator in any rapidly-growing field benefits from the ready accessibility of papers dealing with his area of interest. In general, private reprint collections are filed according to subject matter. Nearly all papers can be filed under several headings. Unless one laboriously cross-indexes the file, it is often difficult to find a specific piece of information. Even if there were no ambiguity at the time of filing, a researcher's interest changes over the years so that many categories in the filing system become obsolete, or forgotten. A single category filing system does not allow one to extract a paper by author's name or by the intersection of multiple categories. For these reasons, it appeared desirable to develop a more versatile information retrieval system which would allow papers, books, catalogues, etc., to be located via a wide variety of categories or keywords.

The system for an individual researcher's reference library which is at present being used for the reprint files of the Nuclear Medicine Division at Vanderbilt University will be described. The system requires that the investigator have a set of IBM cards prepared which indicate the names and addresses of the authors, title of article, journal name, and citation. The computer generates letters requesting reprints, and control listings. These are proofread before being merged with the main files. When reprints are received, an accession number is assigned by the secretary, and key words by the investigator. Documents are filed by accession number.

The system allows the investigator to find in an alphabetic list of subjects or keywords the location in his filing system of all the papers coded as dealing with that subject.

In addition to generating lists of document locations vs. subject matter and providing a catalogue of file inclusions by author name, the computer also provides a bibliography ordered by article accession number. When preparing articles for publication, the references to be cited can be called for and listed in appropriate sequence without further verification of the accuracy of the typed citation.

This system, which allows the use of 1439 key words and 1000 articles per keyword, has been written for an IBM 7072, with a 10 K word memory and five magnetic tapes. However, the system could be run on a computer with as few as three tapes, and the core memory requirements could be lowered with some sacrifice in elegance. On the other hand, a larger machine would allow the use of more keywords.

In addition, with appropriate keywords, such a system can be used for retrieval of other types of information in a hospital. For example, pathology specimens, and X-ray film files including multiple descriptors of findings and patient characteristics.

30. *"Production of 70-Day Tungsten-188 and Development of a 17 Hour Rhenium-188 Radioisotope Generator."*[2] R. E. Lewis and J. S. Eldridge, (Isotopes Development Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee)

The parameters for production of 70-d tungsten-188 by double neutron capture in tungsten-186 targets and the development of a tungsten-188–rhenium-188 radioisotope generator are described.

The biochemical similarity of perrhenate to pertechnetate and iodide has been demonstrated in thyroid tissue and recently in animal studies. The radiation characteristics of rhenium-188 are useful in thyroid scanning because of a 0.155-MeV gamma and 0.062-MeV x-ray with <2% higher energy gammas. A possible disadvantage of rhenium-188 for use in medical scanning is the high percentage of 1.96- and 2.12-MeV beta particles per disintegra-

[1]These studies were supported by the U.S. Atomic Energy Commission, Contract AT-(40-1)-2401.

[2]Research sponsored by the U. S. Atomic Energy Commission under contract with the Union Carbide Corporation.

tion. Half-life measurements and gamma-ray branching are being studied at present to develop absolute radioassay methods for tungsten-188 and rhenium-188.

Targets of enriched tungsten-186 were irradiated in several reactor positions. It was found that the production rate of tungsten-188 was greater in reactor positions having a higher epithermal neutron flux than in positions with a well-thermalized neutron flux. The thermal cross sections and effective resonance integrals of the $^{186}W(n,\gamma)^{187}W$ and $^{187}W(n,\gamma)^{188}W$ reactions were determined. Production of hundred millicurie quantities of tungsten-188 was demonstrated by irradiation of tungsten-186 in neutron fluxes $>1 \times 10^{15}$ n/cm^2.sec.

A radioisotope generator was prepared by sorbing tungsten-188 as tungstate on the chloride form of Bio-Rad HZO-1, a hydrous zirconium oxide ion exchanger. The rhenium-188 elution and separation from tungsten-188 is achieved in a manner similar to the technique previously described for a molybdenum-99–technetium-99m radioisotope generator. The rhenium-188, as perrhenate, is eluted from the ion exchange column by 95 v/o methyl ethyl ketone–5 v/o 0.01 *M* HCl with 85-90% yield. Water is added to the eluate and the methyl ethyl ketone is evaporated, leaving the rhenium-188 product in weakly acidic solution. An alternate ion exchanger elution procedure is by use of normal saline. The tungsten-188 continuation of the rhenium-188 product is $\sim 1 \times 10^{-4}$% in either case. The tungsten-188–rhenium-188 generator has a much longer shelf life than the molybdenum-99–technetium-99m radioisotope generator because of the longer half-life of tungsten-188 (70-d as compared to 67 hr for molybdenum-99).

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[1]Research sponsored by the U. S. Atomic Energy Commission under contract with the Union Carbide Corporation.

FELLOWSHIP IN NUCLEAR MEDICINE

As part of the multidisciplinary clinical radiotherapy research program, the Nuclear Medicine Division of the Stanford University Department of Radiology invites applications now for a one year Fellowship available on July 1, 1967. The program includes training in isotope methodology as well as clinical and research experience, and is designed for those with a special interest in nuclear medicine and/or oncology. Applicants must have completed two years of post-graduate residence training. Stipend is $8,000 per year.

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