# Abstracts

**Production and Use of High Specific Activity Fluorine-18.** T.J. Tewson. *University of Texas Medical School at Houston, Houston, TX.*

A variety of nuclear reactions are available to produce fluorine-18 and the choice of target material dictates not only the bombardment conditions but also the chemical form in which the radionuclide can be extracted from the target. The advantages and limitations of some current target systems will be discussed.

The only fluorinating agents currently available which are suitable for use with high specific activity fluorine-18 are salts containing the fluorine-19 fluoride ion. To use these salts, an appropriate cation must be added and the cation and its accompanying anion must be tailored to suit the reaction that is to be performed. The majority of the water, both as solvent and water of solution, must be removed before these salts can be used. Removing this water is one, but not the only, requirement for producing usable fluoride salts. A number of reactions are now known that will occur with no carrier added fluorine-18 fluoride in excellent yields, and these are useful for checking the reactivity of the fluorine-18 fluoride solutions produced.

Specific activity measurements must also be performed at different stages. The typical best values for the specific activity of fluorine-18 radiopharmaceuticals is ~5,000 Ci/mmol. This is about three orders of magnitude below the theoretical value. In order to maximize the specific activity, it is necessary to know the origin of the containments. Typically the target, the reagents added to produce the fluoride salts, and the final purification of the product all contribute to the lowering of the specific activity, with the last source being the major contributor. In this case it is very important to distinguish between chemical specific activity and biological specific activity. The former is a measure of how much of the compound made is present in the final solution; the latter is a measurement of how much biologically active material is present in the solution. Typically, the two are not and need not be the same.

**Preparation of High Specific Activity Carbon-11-Labeled Radiotracers.** J.S. Fowler and A.P. Wolf. *Brookhaven National Laboratory, Upton, NY.*

While it is probably not possible to achieve the theoretical specific activity of $9.3 \times 10^3$ Ci/$\mu$mol for carbon-11-labeled radiotracers without a prohibitively large expenditure of time and resources, nonetheless C-11-labeled precursors have been prepared where the dilution of carbon-11 is in the order of $^{12}C/^{11}C = 10^3$-$10^4$. At these levels, human doses of approximately 10 nmol are possible (assuming that 20 mCi/study is required) making it possible to study pharmacologically potent molecules at low risk. Achieving maximum specific activity requires the optimization of both precursor and radiotracer synthesis parameters. Such factors as target substrate purity and pretarget purification systems, integrity of precursor delivery systems, and reagent and substrate purity for the synthesis itself come into play. Analytical systems for measuring the specific activity of the precursor itself before synthesis provide a means for determining the maximum achievable specific activity for the tracer itself.

**Preparation and Specific Activities of Bromine-75.** A.M. Friedman and O.T. DeJesus. *Argonne National Laboratory, Argonne, IL; and University of Chicago, IL.*

The preparation of bromine-75 using gas target and solid target reactions are discussed. The yield and amounts of bromine and other halogen contaminations were measured to obtain the resulting specific activities. It was found that specific activities of approximately 2,200 Ci/mmol were about the upper limit. Particular care has to be exercised to reduce contamination from other halogens.

**Preparation of High Specific Activity Bromine-77.** H.A. O'Brien, Jr., P.M. Grant, J.W. Barnes, G.E. Bentley, and D.S. Wilbur. *Los Alamos National Laboratory, Los Alamos, NM.*

The potential of accelerator-produced radiohalogens for pharmaceutical labels is well known. Over the past few years, numerous studies have been carried out to develop Br-77-labeled agents that would be useful in distinguishing hormone-dependent tumors. More recently, interest has been increasing in the potential applications of Br-77-labeled antibodies for internal radiation therapy of tumors. However, obtaining the radiobrominated compounds in the specific activity required for nonsaturation of the specific receptors has been a difficult task.

At Los Alamos, a great effort has been directed at developing methods for preparing high specific activity Br-77 in high yields. Metallic Mo targets are bombarded with medium energy protons ($\leq$800 MeV) to produce Br-77 by nuclear spallation. Targets up to 2 cm thick are irradiated at LAMPF's Isotope Production Facility, where 50% to 75% of the proton current (950 $\mu$A at present) is available for radionuclide production. Since medium-energy nuclear spallation generates numerous and diverse reaction products, LAMPF-produced Br-77 must undergo extensive radiochemical decontamination from virtually every element in the periodic table from H to

Tc. Following a 7-day irradiation and chemical processing, Br-77 yields of 6,000 mCi to 7,000 mCi are obtained. The specific activity varies between 2,300 Ci/mmol to 3,800 Ci/mmol (29,000-48,000 Ci/g).

Even though this high specific activity material has been used, many of the radiobrominations of estrogens that have been reported have yielded labeled estrogens with specific activities less than, or equal to 1,000 Ci/mmol. Clearly greater care must be exercised in selecting reagents free of, or with low concentrations of, stable bromine.

### Iodine-123 On-Line Collection System from 800 MeV Proton Spallation on CsCl and BaCl₂ Targets.* M.A. Ott, J.W. Barnes, F.H. Seurer, N.J. Segura, P.M. Wanek, W.A. Taylor, F.J. Steinkruger, K.E. Thomas, G.E. Bentley, H.A. O'Brien, and D.C. Moody. Los Alamos Laboratory, Los Alamos, NM.

Interest within the radiopharmaceutical community in obtaining high-purity iodine-123 has grown considerably since the development of radioiodinated agents that show promise in diagnosing cerebrovascular defects (stroke). In the recent past, we have investigated and reported upon spallation yields of iodine-123 via xenon-123 from cesium chloride targets using batch irradiations of 2, 4, and 6 hr [H.A. O'Brien, Jr., J Nucl Med 24: P24, 1983 (abstr)]. Results have shown that with a 4-hr irradiation/4-hr growth, approximately 800 mCi of iodine-123 can be recovered at the end of growth. The iodine-125 contamination at that time is ~0.6%. Considering the decay between end of growth and time of patient injection, the iodine-125 concentrations that we have observed are on the borderline of acceptability.

In order to determine the role of spallation reactions in future production of high purity iodine-123, it is necessary to evaluate an on-line xenon-123 production system. Given the unique constraints of the Isotope Production Facility (IPF) at the Los Alamos Meson Physics Facility (LAMPF), we have designed a system (based on an adaptation of helium flow and xenon recovery systems currently in use at Crocker Nuclear Laboratory and at TRIUMF) that will allow irradiations with encapsulated targets at beam intensities between 400 $\mu$A and 900 $\mu$A, and recovery of spallation produced xenon-123 in a shielded trapping system. The system is somewhat unique in that the liquid nitrogen trap (generator) is contained within a lead transport shield which, following completion of irradiation, is used to move the radioxenons collected approximately 6 miles to the processing facility.

The preliminary results of three identical runs, using a barium chloride target, are encouraging in that a 2-hr irradiation followed by a 2-hr growth period in the generator resulted in 556 mCi iodine-123 with a 1.2 mCi iodine-125 contamination (0.22%). An additional 4-hr growth period for the xenons that were removed from the generator yielded another 188 mCi iodine-123 with 1.3 mCi iodine-125 (0.7%). A 1-hr irradiation followed by a 2-hr growth period yielded 329 mCi iodine-123 with 0.60 mCi iodine-125 (0.18%). Both runs occurred while the beam current was approximately 570 $\mu$A. Another 2-hr irradiation at slightly higher beam current, fol-

lowed by a 2-hr growth period, yielded 590 mCi iodine-123 with 1.26 mCi iodine-125 contamination (0.21%).

### Production of High Purity Iodine-123 Using Xenon-124. D. Graham, I.C. Trevena, B. Webster, and D. Williams. Atomic Energy of Canada Limited, Vancouver, Canada.

The standard for high purity I-123 has been set by product obtained from the I-127 (p,5n) reaction. However, this reaction requires energies beyond the capabilities of compact industrial cyclotrons. Since 1981, Atomic Energy of Canada has been developing a means of producing I-123 using the reactions

$$^{124}Xe\ (p,2n)\ ^{123}Cs \rightarrow\ ^{123}Xe \rightarrow\ ^{123}I$$
$$^{124}Xe\ (p,pn)\ ^{123}Xe \rightarrow\ ^{123}I$$
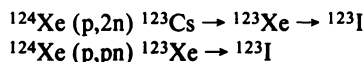
In order to provide commercial quantities of I-123, enriched Xe-124 is used and the gas target is operated routinely at 75 $\mu$A. Since the value of the gas in the target during irradiation is about $50,000, the target must be secure and the processing system must ensure negligible losses. Since the final modification to the target window cooling system was made in March 1984, there have been no gas losses arising from target window failure. Until October 1984, each process had associated with it a loss of about 3 ml of enriched gas (~$500). This loss has now been eliminated.

At the end of irradiation, product may be obtained from two sources: from decay of cryogenically separated xenon gas or by washing the target. The yield from both sources, at the end of processing, 3 hr after end of bombardment is about 3 mCi/$\mu$Ah. Product from the gas phase may be supplied with no detectable impurities whereas product from the wash of the target contains <0.001% I-125 and <0.005% Te-121. Iodine-124 and I-126 are about 0.00005%.

Since August 1984, AECL has been producing this high purity I-123 in 2 Ci batches once per week. The product has been supplied in 1% NH₄OH for labeling applications. This solution may be readily evaporated to a low volume without the solid mass associated with a solution such as dilute sodium hydroxide.

### Production of High Specific Activity (p,5n) Iodine-123 for Receptor Labeling. M. Lagunas-Solar. Radioisotope Program, Crocker Nuclear Laboratory, University of California, Davis, CA.

Since 1970, the UC Davis's Crocker Nuclear Laboratory 76-in. isochronous cyclotron has been used for the development and production of several radionuclides intended for diagnostic nuclear medicine applications. Recently, and due to the potential of many new I-123-labeled radiopharmaceuticals under investigation (receptor-binding, antibodies and/or fragments, brain agents, etc.), the need for large-scale production of high-purity I-123 has been recognized to the extent that facilities matching the UC Davis's accelerator are being built. Among the several different methods presently in use for the production of I-123, the indirect method developed at UC Davis based upon the $^{127}I$ (p,5n) $^{123}Xe$ (2.1 hr) $\rightarrow$ $^{123}I$ (13.29 hr) nuclear reaction is recognized today as the method of choice

when high radionuclidic purity I-123 is desired. Iodine-123 produced by this method has less than 0.10% (at end-of-processing) of 60-day I-125 as the only radioiodine impurity. In addition, the indirect method offers ample opportunities for producing high specific activity I-123, in a variety of aqueous and/or organic solvents, and with high radioactivity concentrations (mCi/ml). These latter characteristics are highly desirable for direct iodinated labeling.

### Preparation and Quality Control of High Purity I-123 at the BLIP. L.F. Mausner. Brookhaven National Laboratory, Upton, NY.

The usefulness in diagnostic nuclear medicine of I-123 has long been recognized. For many newer applications, very careful control of radiopurity, chemical species, and specific activity is required. We prepare I-123 by bombarding a sodium iodide target with 68 MeV protons from the BLIP (Brookhaven Linac Isotope Producer) leading to the nuclear reaction $^{127}I(p,5n)^{123}Xe \rightarrow ^{123}I$. Great care must be taken to prevent any of the massive quantity of target iodide from accompanying the xenon. The activity is supplied in a small Pyrex glass ampoule with the I-123 generated from the decay of Xe-123 deposited on the interior walls. This unique method allows maximum flexibility in iodinations because reactions can be carried out directly in the ampoule or the activity rinsed out with any desired solvent compatible with subsequent iodination steps. The radiopurity is excellent (no $^{124}I$; $^{125}I/^{123}I$ <0.005; $^{121}I/^{123}I$ <2 × $10^{-5}$ at 9 a.m. day of receipt) and the chemical form is very suitable for most labeling reactions (I⁻ >95% by high performance liquid chromatography if rinsed with base). Measurements of specific activity by x-ray fluorescence, neutron activation, uv absorption, and wet chemistry will be described.

Although capable of yielding high quality I-123, the present batch procedure is relatively time consuming and inefficient. Therefore, we have begun to investigate the construction of a processing system wherein helium gas flowing through a molten sodium iodide target sweeps out the Xe-123 produced during bombardment and carries it directly to a trap. There are minimal Xe-123 decay losses giving much higher I-123 yield than achievable using a batch mode, and with less required manpower.

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*Abstracts in this section pertain to papers presented at the meeting of SNM's Computer and Instrumentation Councils, "Advances in Nuclear Medicine Instrumentation and Data Processing," January 28-29, 1985, Las Vegas. Program Chairmen: Bryan Westerman, PhD, and Michael Goris, MD, PhD.*

the small, typical, nuclear cardiology-oriented, interdisciplinary group presently involved in some animal research can initiate research and make contributions in phosphorus cardiac NMR spectroscopy and undertake this endeavor for an equipment investment of approximately the cost of a gamma-camera. In making this statement, we presume the existence and access to a whole-body NMR imager with spectroscopy capability or to a small-bore spectrometer.

### Phosphorus NMR Spectroscopy of the Heart: A Critical Review of Research Findings To Date, an In-Depth Review of Surface-Coil Technology and an Identification of Necessary Radiofrequency Instrumentation. D.L. Williams, J.L. Ritchie, J.H. Caldwell, and M.D. Cerqueira. VA Medical Center; and University of Washington, Seattle, WA.

As a precursor to a decision of active involvement in cardiac phosphorus NMR studies in our existing dog isotope model, we have made an intensive search of the literature to identify and understand published research in this area of investigation.

We have reviewed the scientific progress which has been made since the first in vivo, intact measurement of phosphorus energetics in muscle by Hoult et al., 1974, up through the recent gated cardiac spectroscopy of Hollis et al. Surface-coil technology has been similarly treated. The types and costs of radiofrequency instrumentation necessary for a coil-development laboratory have also been identified. We conclude that

### Dynamic Cardiac Magnetic Resonance Imaging: Application of Post-Acquisition Digital Processing. D.H. Feiglin, R.T. Go, J.K. O'Donnell, and W.J. MacIntyre. Cleveland Clinic Foundation, Cleveland, OH.

Routine acquisition techniques of gated magnetic resonance (MR) imaging of the heart involve multiple anatomic slices. Each slice of a multislice sequence involves a finite acquisition time, so that the sequence does not allow for visualization of cardiac anatomy at the same phase of the cardiac cycle. Variation of the multislice sequence allows for acquisition of any slice at any phase of the cardiac cycle so that by performing a series of multislice acquisitions sufficient data can be obtained. In general, adequate image data can be obtained using only cardiac gating and two signal averages. Acquisition time is dependent on the patient's heart rate, requiring about 260 pulse sequences, and is in the range of 2 to 5 min. Ideally, if N slices are requested then N multislice sequences should be obtained giving an N × N set of data matrices. In a clinical setting, the use of M multislice sequences, where M < N, has

been found to be sufficient for evaluation of cardiac anatomic function including the motion of chambers and valvular structures. Values of N vary from 8 to 15 and values of M from 4 to 10. The number of slices, N, are limited by the number of echos desired in a spin-echo pulse sequence as well as the pulse repetition rate TR. The latter is determined by the patient's heart rate. It can be inferred that injudicious selection of slicing thickness may preclude full evaluation of the heart's anatomic structure as the total slicing time may exceed the TR selected. Total data acquisition time is in the range of 20 to 40 min.

Image processing on the VICOM display system allows reformatting of data so that up to nine 170 × 170 matrices can be displayed in a 512 × 512 window. Availability of at least eight image memory planes allows for cine display at rates of up to 30 frames/sec. Appropriate formatting allows each slice from the multislice sequence to be in the same phase of the cardiac cycle. Simple algorithms allow thresholding, windowing, and zooming as well as color display similar to those available with nuclear medicine software but using higher order matrices. Experience since March 1984 suggests that dynamic gated cardiac MR imaging is the technique of choice for structural and functional cardiac evaluation.

**High Energy Collimator Selection for a Scintillation Camera System.** R.F. Johnson, Jr., W.R. Day, H. Sobhani, and M.L. Nusynowitz. *University of Texas Medical Branch, Galveston, TX.*

Scintillation camera collimation for the high energy photons emitted by I-131 is difficult to achieve with modern high resolution camera systems. Whereas the demand for clinical imaging of I-131 may not be great, it still exists for those situations where I-131 therapy is utilized. The demise of the rectilinear scanner has placed the burden of imaging I-131 on the Anger camera, a device not as well suited for adequate collimation of the 365 keV photons. Collimator design for the high energy photons requires such quantities of lead in the septal walls that the holes become either too large and are resolved by the camera, or too few in number to provide adequate sensitivity for imaging. Optimal balance of resolution, sensitivity, and uniformity is desirable but difficult to find in commercial camera collimators for I-131.

Four collimators designed for imaging I-131 were tested for performance on a Technicare Sigma 438 large field of view camera system. Technicare provided three iodine collimators made by a collimator manufacturer and one iodine collimator designed by Technicare. Line source response measurements were recorded at the surface and at 10 cm for Tc-99m and I-131 for each of the four collimators. Modulation transfer function data were generated to measure resolution performance. Each collimator was evaluated for sensitivity and uniformity response as additional criteria for selecting the best collimator for imaging I-131.

One collimator, principally designed for imaging Ga-67 or In-111 but with "extended energy range" according to the manufacturer, had the best resolution with Tc-99m but the poorest I-131 resolution; it was totally inadequate for imaging I-131. The other three collimators differed only slightly in Tc-99m and I-131 resolution according to MTF measurements. One of these collimators had gross nonuniformity artifacts which also precluded its clinical use. The final two collimators

compared exactly in resolution, but one had superior sensitivity whereas the other was not only less sensitive but demonstrated poorer uniformity.

In summary, four collimators were compared for performance in resolution, sensitivity, and uniformity with one clearly showing the best overall characteristics. The evaluation was critical in the selection process because the choice based on published specifications supplied by the manufacturer was not reliable.

**Dependence of Measured Diastolic Function on Acquisition Mode: Gated vs. List.** T.K. Johnson, R.J. Boudreau, and M.K. Loken. *University of Minnesota, Minneapolis, MN.*

Fourier analysis is one method of analyzing left ventricular time-activity curves (TAC) to determine peak filling rate (PFR) and time to peak filling (TPF). A variable number of harmonics must be used in order to fit the curve adequately, the exact number being individually tailored to each study in order to compromise between the fitting of noise and the fitting of data. This task is easier when the TAC is regular and continuous. Unfortunately, when one acquires data in gated mode, irregularities in heart rate result in TAC count drop-off. To determine the effect that this count drop-off might have on measured diastolic function, TACs were acquired from 20 patients in both list and gated acquisition modes. Following Fourier fitting with a variable number of harmonics, these were compared with respect to TPF and PFR.

Values derived from gated studies with regular TACs quickly converged after the addition of several harmonics. Those suffering count drop-off, however, developed increasing numbers of inflection points as the number of included harmonics increased. This resulted in ambiguous or erroneous selection of the TPF and calculation of the PFR. We are currently investigating several approaches to correction of the gated TAC so as to eliminate this problem. The list mode acquisitions, which effectually eliminate the phenomenon of count drop-off, almost invariably did not suffer from this anomaly.

These findings argue strongly against "canned" programs that: (a) are invisible to the user as regards identification of timing parameters (TPF); (b) utilize a fixed number of harmonics in the fitting of TACs; and (c) do not display the TAC, Fourier fit, and inflection points for verification.

Until all nuclear medicine computer facilities have either buffered acquisition to simulate list mode, routinely use list mode, or develop satisfactory algorithms to correct for count drop-off, quantitative analysis of diastolic function should be scrutinized with care. Automated processing of TACs will require the development of more sophisticated heuristics than are presently in routine use.

**Analytical Reconstruction of Electronically Collimated Single Photon Images.** W.P. Kowalsky and R.L. Van Heertum. *St. Vincent's Hospital and Medical Center, New York, NY.*

An analytical method for the reconstruction of electronically collimated single photon emission images has been developed. The method assumes dual parallel detector planes in which photons scattered by Compton interactions in the first plane

are photoelectrically absorbed in the second. Both detector planes are assumed to have high spatial and energy resolution, although excellent energy resolution is critical only for the first plane. Electronic sorting of incoming counts may be used to produce a series of two dimensional projection images which differ from one another in one or both of two parameters: (a) the point of interaction in the first plane; and (b) the Compton scattering angle.

The problem of reconstruction has been decomposed into two parts. In the first part, each projection image is analyzed independently. The superimposed elliptical count patterns due to each line of activity from the source distribution to the point of interaction in the first detector plane are separated and condensed to a pinhole image. This is accomplished by applying transform theory to the first order inhomogeneous Friedholm integral equation governing the system. A three dimensional Fourier-Hilbert transform of the required pinhole image is obtained from the two dimensional projection data. Equations of dependence between the dimensional variables allow the three dimensional transform to be inverted into a two dimensional pinhole image of the source distribution. The number of pinhole images is theoretically limited only by the spatial and energy resolution of the first detector plane and is equal to the number of projection images.

The second part of the reconstruction process combines all of the pinhole images into a three dimensional image of the original activity distribution. To this end, Fourier techniques are applied in a manner similar to that used in positron emission tomography reconstruction.

### Suitability of Microcomputer Systems for Numerical Analysis of Medical Images. S.M. Spies, E.A. Silverstein, and W.G. Spies. *Northwestern University Medical School, Chicago, IL.*

Over the past several years, the data processing requirements in nuclear medicine have increased steadily. Today, isotope ventriculography, myocardial perfusion imaging, renal studies, and emission computed tomographic (ECT) studies all have substantial computational overhead. Many departments are using traditional minicomputer-based nuclear medicine computer systems which trace their ancestry to products developed during the early and mid-1970s. Recognizing both the disadvantages of this older technology, and, at the same time, the dramatic growth and development of modern microprocessor systems, we have studied the feasibility of using these newer systems for nuclear medicine computation and display.

Our evaluation considered three important aspects of system performance: (a) computational speed; (b) availability of suitable operating systems; and (c) ease of application program development. Speed was tested, running several benchmark programs which we developed to measure manipulations typical of those found in nuclear medicine image processing algorithms. These benchmarks were designed to allow independent assessment of system I/O performance and actual computational performance. Operating system suitability was determined by comparing seven commercially available operating systems. Finally, the effectiveness of the programming environment was assessed by actual program development in several languages (Fortran 77, Pascal, C, Assembler).

The results of benchmark program runs indicate that typical 16 bit microcomputer systems are capable of throughput two to six times that of a typical nuclear medicine minicomputer. Sophisticated operating systems are readily available which in many cases outperform the established minicomputer system software at a fraction of the cost. A large variety of program development tools exist making application program development on the microcomputer a straightforward task. We conclude that the replacement of older microcomputer systems with newer generation microcomputers is not only feasible, but highly desirable, both from an absolute performance standpoint and from a monetary standpoint as well.

### Co-Processors for Departmental Administrative Tasks. V.M. Spitzer and S.B. Patterson. *University of Colorado Health Sciences Center; and Micro Link, Inc., Denver, CO.*

The impact of personal computer (PC) technology and mass production on nuclear medicine departments includes both lower peripheral costs (printers, disks, and tapes) and smaller, more capable, system packages. Software from the PC world, on the other hand, is only slowly assimilated into the imaging computers prevalent in nuclear medicine. For a very select number of departments, hospital information management systems, or more specific radiology patient management systems are in place, working and available for patient information management as well as department specific tasks such as radiation safety data management. A majority of departments still operate with hand recording and management of data or utilize job-specific individual processors for each task. If multiple management CPUs are currently installed, and if they are of reasonably similar architecture, then local area networking is becoming more readily available for such an installation.

An alternative approach which we are implementing, under severe monetary constraints, is the use of co-processors on existing departmental computers to provide access to the least expensive and most expansive source of management software—PC software. Our system now provides access to the volumes of software currently available under CP/M.

Our system includes Z80A CPUs with 60 Kbyte CP/M software from a host DEC RT-11 operating system. The host CPU must provide DEC Q-BUS access and run under RT-11. ADAC, CDA, and GAMMA-11 can all provide this host function although we utilize a PDP 11/03 from a HARSHAW rCBF device. Each new management task that must be executed in a new area of the department requires a new co-processor and terminal, but mass storage and printers are always common resources on the host RT-11 system. Applications include patient and examination statistics, word processing report generation, radioisotope distribution recordkeeping, and examination cost determination data. The advantages of such a system include common data dictionaries, shared peripheral devices, and, most importantly, access to a vast supply of cheap management software.

### A Dedicated Nuclear Medicine Data Acquisition System. S.M. Spies, E.A. Silverstein, and W.G. Spies. *Northwestern University, Chicago, IL.*

The purpose of this study was to design and construct a data acquisition system suitable for interfacing to conventional

gamma cameras. Such a system could replace the large, costly, and difficult to maintain microcomputer-based systems which are commonly used in nuclear medicine departments today.

We have taken advantage of recent advances in microprocessor technology in constructing a high-performance, microcomputer-based acquisition system. The system employs an Intel 8086-family CPU with 512 Kbytes of RAM. The analog front-end design incorporates high speed (2.2 $\mu$sec) successive approximation ADCs with 10 bits of resolution, derandomizing buffers to optimize throughput, variable gain input to allow interfacing to most nuclear medicine imaging systems, and associated bus interface and control logic, all on a single circuit board.

To ensure portability and ease of upward migration, the majority of the system software has been developed in C. Only a few time-critical modules are written in 8086 assembly language. The software provides for acquisition of static, dynamic, and ECT studies. ECT acquisition includes appropriate routines for gantry control, uniformity correction, and offset correction of raw projection data. Patient demographic and image data are stored on magnetic media (floppy or rigid disks) until transfer of data to an analysis station is initiated over standard serial (RS232C at 9600-19200 baud) or parallel interfaces. The system is readily adaptable to data transfer over standard local area networks as well.

Results of phantom and routine patient studies have verified the performance of the acquisition system in all modes described. The system has proven to be reliable, easy to operate, and extremely cost-effective. We feel that this approach to nuclear medicine data acquisition offers numerous advantages over more conventional approaches and should be considered as an alternative to microcomputer-based systems.

**A Powerful and Cost-Effective All-Digital Nuclear Medicine System.** T.R. Miller and K.S. Sampathkumaran. *Mallinckrodt Institute of Radiology, Washington University School of Medicine, St. Louis, MO.*

We have developed an all-digital image acquisition, display, and analysis system for use in a large nuclear medicine department. The requirements of this system are that it include a powerful central processor, operate reliably, be moderate in cost, and serve as a subnetwork node in a much larger radiology-wide picture archiving and communications system (PACS).

The VAX-11/750 32-bit computer (Digital Equipment Corp.) was selected as the central processor because of its speed, memory, and disk capacity, and because of the wide availability of compatible computers and peripheral devices. Images from each of six scintillation cameras are digitized and stored in PDP-11/24 or PDP-11/34 16-bit computers (Digital Equipment Corp.) equipped with floppy disk drives and analog-to-digital converters, but without separate, expensive video display systems. After collection in the PDP-11 computers, the images are transmitted over point-to-point network links to the VAX.

All images generated during a 2-wk interval are kept on a 456 Mbyte disk attached to the central processor, thus permitting immediate access to these data. As the images are written to the VAX disk, they are also automatically transferred via a DEC net link to a central radiology archive holding several months of images on optical disk.

Processing of the digital data is performed in the VAX, with computation-intensive digital filtering performed automatically in a low-priority, batch-mode job, and user-interactive analysis and image interpretation performed simultaneously at three work stations equipped with high-quality video display systems. Processing and analysis is not performed in the separate, small PDP-11 computers because they are always in use collecting images and because of their much inferior computational power and versatility.

Cost containment is achieved through purchase of used PDP-11 computers costing $16,000 each. The system is reliable since failure of any PDP-11 does not affect acquisition from the other cameras. The cost of the VAX-11/750 with 3 Mbyte main memory, 600 Mbyte disk storage, and three video systems is $145,000. Thus, the total cost for an all-digital department with six cameras and three independent display and analysis stations is $241,000.

**Managing the Nuclear Medicine Laboratory with Personal Computers.** R.E. Henry, J.L. Davis, and B.F. Mason. *University of Arizona; and VA Medical Center, Tucson, AZ.*

When we evaluated word processors, it became apparent that personal computers (PCs) and off-the-shelf software could manage laboratory problems effectively and inexpensively. We purchased two Apple IIe computers with floppy disk drives, one 5 Mbyte hard disk, a dot matrix printer and a letter-quality printer for $7,000 which handled all the applications described. Two PCs and another printer were added later for physician and physicist use. Word processing, database, and spreadsheet programs totaled $600. At least three programs of each type were examined before purchase and implementation.

The word processor improved quality and reduced turnaround time for procedure reports. Transcription drafts are corrected by resident and attending physicians and final reports are prepared quickly. Information appearing in all reports is entered only once and a glossary of standard phrases, sentences, and paragraphs entered by a single keystroke can be generated. Preparation of a lexicon for automatic report generation by nontypists is in progress.

The database was easily learned and sets up quickly for multiple tasks. A patient registration system allows tracking of procedures, patients, and reports. Nontypists generate the daily schedule and lists of unscheduled patients. The receptionist can access all information on any patient, including a brief interpretation, in a few seconds. Other uses of the database included easy generation and formatting of a laboratory procedure manual by technologists, production of the monthly schedule of work and on-call assignments, and a random access teaching file.

The spreadsheet was used for budget control and tracking of purchases but we switched to the less flexible database because it was easier to use. The spreadsheet calculated the cost of procedures and recalculates instantly if a change in salaries or other cost is entered.

PCs are an inexpensive means to solve multiple management problems in a low-volume department. They have better employee acceptance than mainframe computers and are easier

to learn and operate. Commercially available software is easily adapted to laboratory use and can be implemented by clerks and technologists without prolonged training periods.

**Generating Digital Halftones in a Nuclear Medicine Laboratory.** T. Lowinger, V.S. Savant, and S.J. Goldsmith. *Mt. Sinai Medical Center, New York, NY.*

A halftone is a rendition of a full gray-scale image by a process that produces the subjective effect of continuous tone by properly controlling the spatial density of bilevel display states.

The present work attempts to make possible image reproduction as part of computer-generated reports, as well as to speed publishing nuclear medicine images, by composing and generating halftones in the nuclear medicine department. The final document can then be telecommunicated or transferred on magnetic media to a commercial printer. This would obviate the step of screening and photographing the original images to produce the halftones.

Two methods of generating digital halftones of nuclear medicine images were examined. The first technique, the exploded pixel method, uses a number of bilevel cells to form each pixel. This technique can be used for nuclear medicine images because these images have low spatial resolution and low signal/noise ratios, thus creating a number of bilevel cells to form an image element which does not make inordinate demands on computer memory. It produces halftones comparable to those in newspapers, roughly 100 lines per inch, and is applicable for nuclear medicine images acquired in 64 × 64 matrices. The second method is an ordered dither technique in which a pixel intensity is set as either bright or black depending upon a unique, threshold value. In the ordered dither technique, the threshold is spatially dependent and is determined by the coordinates of the pixel being processed. This technique is more suited to larger matrices.

In this study a mobile scintillation camera interfaced to a Technicare VIP 550 consisting of a motorola MC6800 microprocessor, 64 Kbyte memory and two disk drives was used. There is a 5-in. CRT display with dedicated image memory capable of displaying images of up to 256 × 256 matrix size and 16 shades of gray. Analysis of the acquired scintillation images is performed on the microprocessor system. Hardcopy can be obtained by photographing the display. Program was written in BASIC; processing time for a 64 × 64 matrix was 12 min.

Using the exploded pixel technique, halftones of typical nuclear medicine images, bone, lung, and solitary frames from a gated blood-pool study, were obtained. These images were aesthetically pleasing and satisfactory for interpretation and conference demonstration purposes. With the dithering method, there was some loss of gray scale resolution which was to be expected since the matrix size required would be 512 × 512.

Halftone images of nuclear scintigraphic studies can be generated using equipment readily available in a nuclear medicine department. Initial evaluation suggests that the "exploded pixel" method is preferable to the "dither" technique. There is potential use for this procedure in computer-generated reports and/or manuscript publication.

**The Effect of Mode of Presentation on the Detection of Small Radiation Sources.** M.C. Borgstrom, H.B. Barber, G.W. Seeley, J.M. Woolfenden, and D.D. Patton. *University of Arizona Health Sciences Center, Tucson, AZ.*

For the detection of radiotracer-labeled tumors, an alternative to external imaging is the use of a small probe containing a radiation detector that can be maneuvered in proximity to the tumor during surgery or endoscopy. The detection problem is the classic one of recognizing a small signal due to the source amidst the stochastic variation of the background rate due to the nontarget uptake of the radiotracer. A collateral problem is to find an effective and efficient means of presenting this data to the clinician while he/she is otherwise occupied with the clinical or endoscopic procedure. We have simulated this problem by a procedure in which a NaI(Tl) detector probe is used to search a flat phantom containing small cobalt-57 sources representing tumors. Another source was affixed to the detector and provided the background.

An observer performance study was done to compare three modes of presentation: a rate meter, a rate dependent tone generator (Howler), and multichannel scaling with a multichannel analyzer. Six observers were asked to rate their certainty that a radiation source was present in each of 36 trials positioned on a six-by-six grid in which nine sources of differing activity were hidden. This procedure was repeated for each presentation mode in a random sequence. After each observer responded to all modes, the complete procedure was repeated in a different sequence with a different configuration of sources. Receiver operating characteristic (ROC) curves were generated from observer data. The area under the ROC curve was used as the figure of merit for comparing the three modes of presentation. Obtained area under the curve for the rate meter was 0.73 (s.e.m. = 0.07), for the Howler was 0.68 (s.e.m. = 0.08), and for multichannel scaling, 0.92 (s.e.m. = 0.03). Superior performance of multichannel scaling may justify its added complexity in a clinical setting.

**Problems Inherent in Developing a Total Digital Radiology Department.** G.W. Seeley, H.D. Fisher, M.O. Stempski, and M. Borgstrom. *University of Arizona Health Sciences Center, Tucson, AZ.*

There is currently a massive and sustained effort on the part of the radiologic community and allied disciplines to address the problems inherent in developing a total digital radiology department (TDRD). There have been three major international conferences dealing with the subject of such a system. Prototypes and workbenches have been set up to learn the needs of such a system and to evaluate the hardware being developed to fit into the TDRD. Standards are being proposed and discussed, and a committee which is the joint effort of the American College of Radiology and the National Electrical Manufacturers Association has been formed.

The radiology department of the University of Arizona Health Sciences Center is involved in a 5-yr project to develop a prototype for a TDRD. One prerequisite for such a department is that the system must have the ability to allow the radiologist to perform at the same level as with the existing film-based system. The amount of spatial and contrast resolution that is required to equate the diagnostic information in

chest films will impact directly on the capabilities of the equipment needed to image, transmit, display, and store such images. Therefore, this is a crucial question that must be addressed not only because of its diagnostic import, but also because of its engineering implications.

### An Interactive Computer Program for Designing and Running Psychophysical Experiments. G.W. Seeley, M. Borgstrom, and J. Mazzeo. *University of Arizona Health Sciences Center, Tucson, AZ.*

This paper describes a software system that controls the presentation of stimuli and the taking of data for psychophysical experiments. It consists of two interactive computer programs written in FORTRAN for both the DEC VAX-11/780 and a 64-Kbyte DEC 11/34. The two main programs are called DESIGNMOD and RUNEXP. In general, the first program enables the experimenter to specify all the elements of the experiment, and these elements are used by the second program to run the experiment. The code, and especially the logic, should be easily transferable to other computer systems. For greatest ease of transfer, the computer system's FORTRAN should have BYTE or LOGICAL*1 declaration, "Q" FORMAT, and the capability of adding extensions to file names.

### Stationary and Nonstationary Spatial Domain Metz Filtering Using an Array Processor. M.A. King, T.R. Miller, P.W. Doherty, and R.B. Schwinger. *University of Massachusetts Medical School, Worcester, MA; and Mallinckrodt Institute of Radiology, St. Louis, MO.*

Unlike stationary image processing where a single filter is employed, in nonstationary image processing the filter can be varied to adapt locally to the image. Nonstationary spatial domain finite impulse response (FIR) techniques can be implemented without a significant increase in execution time over stationary processing, thus making them attractive to investigate for clinical use. The purpose of this study was to develop and compare "optimal" stationary and nonstationary FIR implementations of the count-dependent Metz filter on the array processor (AP400). The criterion used was that of minimizing the normalized mean square error (NMSE) between simulated object/image pairs of the Alderson liver phantom at five different count levels. The FIR were filters obtained from the desired frequency domain form using the Chebyshev optimization technique of McClellan. Two different size (15 × 15 and 23 × 23) stationary FIR filters were optimized for the 128 × 128 pixel simulated object/image pairs. Nonstationary filtering was performed by having the array processor select from among 16 preformed filters according to the pixel count. This added less than a tenth of a second to the processing time compared to that of the stationary filtering of 128 × 128 pixel images. No nonstationary FIR filtering technique was observed to give a lower NMSE than obtainable with the same size stationary filter "optimized" for a given count level object/image pair. Nonstationary implementations were thus obtained by filtering each pixel with the filter that would have been used to process a study of the same average

count per pixel. Visually this was found to yield images with more noise suppression in low count areas and resolution recovery in high count areas. A localization receiver operating characteristics' study of the detection and localization of spherical "tumors" in images of the Alderson liver phantom is presently underway.

### Noise Reduction in Dynamic Scintigraphy Using Adaptative Frequency-Domain Filtering. A. Bossuyt, R. Luypaert, J. Van Craen, M. Osteaux, and A.B. Brill. *A Z Vrije Universiteit, Brussels, Belgium; and Brookhaven National Laboratory, Upton, NY.*

Convolution smoothing in space or time domain has been widely applied with the aim of reducing the noise contributions in dynamic scintigraphy. Such processing techniques do not use any a priori information about the process under study. It was our purpose to develop a filtering technique in the temporal frequency domain which takes into account, as much as possible, our knowledge about the statistical noise propagation in the detected signal. Such a filter may be expected (a) to vary spatially as a function of the signal present in different anatomic structures and (b) to be determined by a criterion which evaluates the noise contribution for a given pixel.

The technique is based on the following observations on simulated noisy time-activity curve (TAC) data: (a) the noise contribution to a TAC is distributed uniformly over its Fourier components; and (b) those Fourier components that contain only noise have a magnitude, $C^*$, to a very good approximation related to the time-independent part $a_0$ of a signal by

$$C^* = (0.44 \pm 0.23)a_0$$

Making use of this information, our filtering technique requires the Fourier components of each pixel's TAC to exceed the 2 s.d. upper limit of $C^*$. Fourier components that do not satisfy this criterion are judged to be indistinguishable from the noise and put equal to zero.

The noise contribution that may persist by choosing 2 s.d. as upper limit can be further reduced by spatial median filtering of the thresholded amplitude images. It is then supposed that nonclustered isolated pixels cannot bear a physiologic meaning. Reconstruction of the TACs on the basis of the residual Fourier components yields the filtered version of the dynamic image series.

The level of noise reduction can be appreciated visually by comparing equilibrium gated cardiac blood-pool studies in which temporal contrast enhancement was performed. This was accomplished by subtracting for each pixel its minimum value from the whole image series before and after the filtering procedure.

A major advantage of the technique is that it conserves information in anatomic borders, which results in improved edge detection. The concepts involved permit the use of any number of harmonics for the reconstruction provided they contain relevant information.

**Application of Singular Value Decomposition to Restoration of Scintigraphic Images.** U. Raff, D. Stroud. *University of Colorado School of Medicine, Denver, CO.*

The low signal-to-noise ratio (SNR) and the poor resolution of scintigraphic images present a serious dilemma to investigators in nuclear medicine imaging. So far, image processing has been limited to improvement of image quality by means of digital FIR filters based on a frequency analysis of the degraded noisy information. Image restoration has been approached lately through the implementation of Wiener filters and count-dependent Metz filters. The high level of count-dependent noise in scintigraphic images makes the task of resolution recovery quite complicated, due to the ill-conditioned nature of the problem.

Our approach to spatial image restoration using the singular value decomposition (SVD) pseudo-inverse filter makes use of the generalized inverse operator which will provide a least-square error, minimum norm estimate of the degraded object, since modeling errors and noise have to be taken into account.

Images of the Picker thyroid phantom were collected with different count densities to simulate standard planar scintigraphic images. The impulse response of the system was modeled with a space variant separable point spread function. The profile of an experimental line spread function was used to construct two blur matrices for rows and columns. Singular values are determined by solving the eigenvalue problem of $BB^t$ and $B^tB$ where $B^t$ stands for the transposed matrix of B. The SVD pseudo-inverse filter allows then to "restore" interactively the degraded image. Since the SVD affects images only through well-defined eigenimages, with both high and low frequencies, noise-free restoration with considerable improvement in contrast and resolution can be achieved.

Our results were based on the comparison of a restored "ideal noise-free image" of the thyroid phantom (200 MC) and low count density images with a SNR ranging from 3:1 to 20:1. Contrast of cold lesions improved up to 100% during the interactive resolution recovery. Lesions that were not visually detectable could be recovered allowing exact sizing. Due to the specific structure of the blur eigenimages (oscillation of eigenvectors), lesions can be effectively restored before the noise begins to influence the restoration. In this case, the ill-conditioned nature of the problem starts to dominate for the particular impulse response chosen and further improvement of resolution is destroyed as one approached a local singularity.

We found that the SVD pseudo-inverse filtering is a powerful tool for lesion detectability and lesion sizing in scintigraphic images of low SNR.

**Evaluation of the Stability of Center of Rotation Correction for the Toshiba GCA 90B.** G.C. McNeill, D.D. Patton, V. Deuskar, M. Ochart, K. Edelman, and B. Wesson. *University of Arizonal Health Sciences Center, Tucson, AZ.*

The correction of variation in the center of rotation for SPECT imaging is crucial to the acquisition of valid, interpretable patient exams. Some manufacturers recommend recalculation of the correction factors on a weekly basis, or more frequently if quality control testing demonstrates the need.

Toshiba Medical makes no specific recommendation on this aspect; therefore, we have begun a weekly series of quality control phantom studies to determine the actual period over which these correction factors remain valid. The estimate of the time between necessary recalculations is 3 mo for this unit.

**SPECT Image Quality and the Community Hospital.** R.E. Henry, B.F. Mason, J.W. Vilani, and J.A. Kotler. *University of Arizona; and VA Medical Center, Tucson, AZ.*

Scientists operating prototype systems in research institutions demonstrated that rotating cameras were capable of producing SPECT images of diagnostic quality. SPECT, however, is far more complex than planar imaging, and community hospital laboratories using production model systems may obtain inferior results despite adherence to the vendor's quality control protocol. Our purpose is to report the problems we encountered and the simple procedures we devised to increase image quality or to verify system performance.

Documentation of mechanical alignment of the detector system and electronic alignment between the camera crystal and computer matrix should be a part of acceptance testing and be repeated periodically since misalignment and electronic drift can occur with time. A rotational study of a point source placed near the mechanical axis of rotation is viewed with cine display. Vertical bobbing of the source suggests misalignment on the Y axis. The 0° image of a SPECT study of a set of line sources placed at mechanical center is flipped on its Y axis and superimposed on the 180° image. Vertical or horizontal displacement of the line sources indicates Y or X misalignment, respectively. Some vendors require a SPECT acquisition of one or more point sources to obtain a number for the center of rotation (COR) to enter into the reconstruction algorithm. Visual assessment of a slice through the center of this source from a reconstruction using this number will check for X axis misalignment and verify the vendor's procedure for COR determination. Acceptance testing should include documentation of the resolution of the system by reconstruction of "lesions" in a phantom.

After acquisition of clinical studies, the angular images are viewed in cine mode. Apparent lateral movement may be normal but rhythmic vertical bobbing indicates the need for an alignment check. Erratic patient movement on the angular images degrades reconstruction resolution and a decision must be made to repeat or abandon the study. Patient movement is prevented by securing all body parts not in the field of view to the table with sheets and towels. A foam wedge under the knees and pillows for the head and neck make the patient more comfortable and able to cooperate for long acquisitions. The technologist views the patient continuously during acquisition to prevent changes in body position that could degrade the study or result in collision with the moving detector. Inclusion of an eccentrically placed point source in a clinical head study allows internal verification of COR and also a means of identifying patient laterality on reconstruction.

Each laboratory has the responsibility for validation of its SPECT system's performance before placing the unit in service. Clinical reconstructions should not be used for diagnosis unless the resolution and alignment of the system has been verified and the rotational study is adequate.

**Optimal Iodoamphetamine SPECT Imaging of the Brain Using Rotating Gamma Cameras.** J.F. Polak, S. Muller, and B.L. Holman. *Harvard Medical School, The Brigham and Women's Hospital, Boston, MA.*

SPECT imaging of the brain using rotating cameras can be implemented in the clinic with minor modifications to current imaging protocols and quality control procedures. In our laboratory, special emphasis is given to the use of [N-isopropyl-p-]iodoamphetamine (IMP) labeled with I-123 produced by the Te-124 $(p,2n)$ reaction.

In order to maximize resolution, a LEAP collimator is selected over a Medium Energy design. The full width at half maximum (FWHM) for both collimators reveals consistently better performance for the LEAP despite heavy contamination of the I-123 by I-124 (4%). The scatter contribution from the object being imaged and the direct interaction of the high energy photons of I-124 in the camera crystal affect the low spatial frequencies of the MTF rather than the high. After tomographic reconstruction, the FWHM and MTF values are consistently better for the LEAP collimator. This finding reflects the actual collimator thickness (in our case 40 mm) and suggests that similar improvements are to be expected with thicker collimators (*J Nucl Med* 24:1065–1069, 1983).

Another critical factor is the collimator-brain distance during imaging. An angled collimator (slanthole) can be used to decrease this distance while still letting the camera head clear the patient's shoulder (*J Nucl Med* 25:495–498, 1984). Although image quality is improved, greater care must be given to quality control procedures and corrections made for geometric distortion in any sagittal or coronal reformatted slices. Correct collimator angulation requires a plot of the position of a point source as a function of angular position of the camera head. With improper angulation, a point source is imaged in different transverse slices during a full 360° rotation.

For a given configuration, the choice of the filter window during reconstruction can also help in maximizing signal-to-noise. The % r.m.s. noise can be shown to decrease significantly if a three dimensional kernel is used. Typically, for an imaging period of 15 min, the three dimensional filter will reduce the % r.m.s. noise in a slice through a phantom from 8.7 to 5.9%.

By selecting a long bore (16-cm-thick) collimator, we have shown that resolution is less dependent on depth while contrast is better preserved [*J Nucl Med* 25:P106, 1984 (abstr)]. By combining this collimator to an optimized filter, one can regain some of the loss in sensitivity which is inherent to the collimator. Typically, for a sensitivity of 0.32, the loss in % r.m.s. can be brought down to 50% by the three dimensional filter. Images obtained using this final configuration and processing protocol give sufficient contrast resolution that even basal ganglia infarcts may be visualized.

We conclude that high quality tomographic imaging of the brain is possible using rotating gamma cameras equipped with special collimators and using optimized three dimensional filters.

**SPECT—Technology and Quality Assurance.** B.Y. Croft. *University of Virginia, Charlottesville, VA.*

Commercial development and the clinical utilization of SPECT continues to grow. Areas identified early in SPECT evolution as potentially limiting have received considerable attention. As an example, the technology for achieving patient-contour orbit is now commercially available from several manufacturers of Anger camera-based SPECT systems. Simultaneously, development continues on multiple-probe-based systems.

Objective comparisons of these two approaches to SPECT requires consideration of energy range, sensitivity, resolution, speed of imaging, and general clinical utility.

Attempts to refine gamma ray attenuation and scatter corrections during reconstruction are also continuing, with the ultimate aim of generating truly quantitative images.

Although considerably less dramatic, the need for quality assurance persists. Experience with SPECT has made it possible to suggest a reasonable quality assurance program which supports the production of consistently high quality images without making excessive demands of either equipment or physicist time.

**On the Intelligence Required of Algorithms for Quantitative Analysis of Time-Activity Curves: Characterization of an Algorithm.** T.K. Johnson and R.J. Boudreau. *University of Minnesota, Minneapolis, MN.*

Recent work in cardiovascular nuclear medicine has focused on quantitative analysis of the left ventricular time-activity curve (TAC), especially diastolic function. In coding a self-contained algorithm to perform these measurements, the programmer is confronted with a plethora of curves generated from a multiplicity of disease states. This often leads to an overwhelmingly complex algorithm if one attempts to analyze correctly all possible TACs without benefit of operator interaction. Compounding this problem is the human propensity for making errors in logic as the code becomes increasingly complex. Should these errors occur, the answers obtained may not correspond to physiologic reality.

Arguments are advanced for the inclusion of minimal operator interaction in the form of decision nodes requiring the selection of two key variables: number of harmonics to be used in the Fourier series fit of the TAC; and verification of valid inflection points. Adoption of this interactive approach implies repeatedly fitting the raw data with several different harmonic values in order that an "intelligent" choice be made as regards the compromise between fitting noise in the data and achieving the best possible fit. It also implies scanning through multiple inflection points for selection of appropriate times-of-occurrence for physiologic parameters of interest. Such a methodology necessarily constrains program execution time, since a global impression of the results of each fit must be retained in order to form a mental data base for comparative purposes.

An algorithm that incorporates these characteristics has been developed. Several serious errors in the evaluation of diastolic function that might occur without operator intervention have been identified.

**Displaying ECT Data as Planar Projections Following Voxel Manipulation and Reorientation: An Approach to Simplified Information Extraction.** M.L. Goris, M. Lamp, and C. Loeb. *Stanford University Medical Center, Stanford, CA.*

The results of emission computed tomography (ECT) are usually represented as a set of slices through three-dimensional image space. This type of display seems better suited to

transmission computed tomography, which yields high resolution density information about all the structures in the slice, and thereby provides more than adequate anatomic reference information. In ECT, however, structures are detected only to the extent that they contain the tracer. In most cases the "normal" part of the target structure is detected as a region of higher count-rate densities on a varying background. In other case the normal distribution is bland and higher count-rate densities represent abnormalities. This and the relatively low spatial resolution yield slices with poor anatomic and positional references.

To facilitate the interpretation of the three-dimensional data, a set of "retroprojection" images are created. Retroprojection images are the images one would obtain by planar scintigraphy if the spatial distribution of the tracer was identical to the count-rate density distribution in the image space. They differ from the real planar images because self-absorption and resolution variation with depth can be controlled and because lower count-rate densities in nontarget regions can be thresholded at the voxel level.

To test the potential value of our approach we have used three types of data: thallium myocardial perfusion studies, which are low contrast studies; bone scintigraphs which are high contrast studies; and liver scintigraphs where deep seated lesions are "hidden" by overlying activity. Our aim is to demonstrate that retroprojection images can be created which are equal or superior to the original planar images, but can be used to illustrate information available on the slice images only.

**Preliminary Report on the Use of Multidimensional Scaling to Identify Features Used in Assessing Liver Scans.** M.O. Stempski, G. Seeley, M. Borgstrom, and D. Patton. *University of Arizona Health Sciences Center, Tucson, AZ.*

This paper reports preliminary work in assessing the pertinent perceptual features employed by radiologists in assessing liver scans. In order to perform this research several conceptual, methodologic, and statistical problems must be solved. The problems most germane to this paper concern computer applications to shorten the time required to present the tremendous number of stimuli required, as well as data manipulation to speed computations.

The experimental paradigm employed in our studies is as follows. Observers view and evaluate for similarity pairs of clinically verified liver scans. For any reasonable number of stimuli, the number of pairwise combinations that must be present becomes impressively large. The similarity data is input to multidimensional scaling (MDS) programs. The output from these programs are the dimensions used by the observers in making their evaluations. We assume that the dimensions are related to physical parameters of the liver scans. These physical parameters may be as simple as size, or as complicated as edge gradients. MDS-derived dimensions can be identified through correlations of these dimensions to subjective ratings or the physical parameters. These correlations are established through the use of multiple regression in the simpler cases and with canonical correlation in the more complex cases.