In reviewing the past 20 years, I have highlighted only a few of the Section's important accomplishments; space permitting, the list could go on and on. The Section's growth, however, has been remarkable. Credit for this must be extended to the continued dedication of each active member who has donated valuable time and effort. With the continued support of its membership, the Section can look forward to further prosperity in this new decade and on into the new century. We are 20 years old and still growing.

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A REVIEW OF INSTRUMENTATION 1970–1990

Any review of this nature spanning a period of 20 years is bound to be tainted by personal reflection and may not represent an objective survey of the field. Providing that factor is kept in mind, it is interesting, nevertheless, to explore how the various factors of radiopharmaceuticals, new technology and competing modalities have influenced the development of nuclear medicine instrumentation. A similar review published five years ago (*1*) described many of these developments and concluded that "significant developments" would occur in the following 15 years. Only five of those fifteen years have passed, and not surprisingly, we already have seen some of those changes.

If one were asked to characterize the past 20 years of nuclear medicine, it would have to be in terms of the improvements to scintillation cameras and the change of emphasis from anatomical diagnoses to those based more on physiology. The rectilinear scanner has all but disappeared except for a few locations that still use them for thyroid scans, and some developing nations that have great difficulty in meeting the high cost of scintillation cameras.

At the beginning of the 1970s, the size of scintillation cameras was limited to ~10–12 inch diameter crystals and the number of photomultipliers was either 19 or 37. The first change that took place was an increase in size to 16 inches diameter. One of the earliest large field of view cameras was manufactured by the now defunct Conuclear Ltd. of Ottawa, Canada (Fig. 1) (*2*). Large field of view cameras now include a range of cameras with rectilinear rather than circular detectors. Figure 1 also shows some other interesting peripherals such as the videotape recorder for data storage, the motorized 35-mm camera for capturing dynamic studies, and the dual-rate meter/pen chart combination for "split crystal" time-activity curves. The peripherals have been replaced by nuclear medicine computers and multi-format cameras which were developed during the 1970s.

It was interesting to observe how, for a short time, crystal thicknesses decreased to ¼ inch with the advent of thallium as a scanning agent. This was done to capture the best spatial resolution available, but the crystal thickness soon went back to the more common $^{3}/_{8}$ inch as resolution was enhanced by means of improved photomultipliers and electronics.

In an effort to improve the uniformity of scintillation cameras, correction circuits were introduced that performed count-skimming or count-adding operations based upon a stored uniformity correction table. Fortunately, it was quickly appreciated that such correction based on the premise that nonuniformity is a sensitivity issue was not correcting the basic problem. With the development of improved digital technology, it was possible to introduce energy and linearity correction circuits that did address the fundamental cause of camera nonuniformity.

The improved performance of scintillation cameras was not accomplished without some detriment. The increasing complexity implied that service engineers took longer to adjust the cameras for optimal performance. Consequently, manufacturers began to investigate ways in which they could automate the tuning process, reduce the service time, improve reliability, and therefore, constrain service costs. Autotune technology took several forms. In some cameras, light-emitting diodes are used to pulse the photomultiplier tubes with a fixed signal that can be used for calibration purposes; in other cases, the tuning is done using the energy of incident photons from either a fixed source geometry or from the patient. In some instances, the tuning process is under operator control; in others, it is a continuous process. Whichever system is adopted, the ultimate goal is to have a camera that remains stable over longer periods of time and can be quickly tuned whenever service is required.

The ongoing objective in scintillation

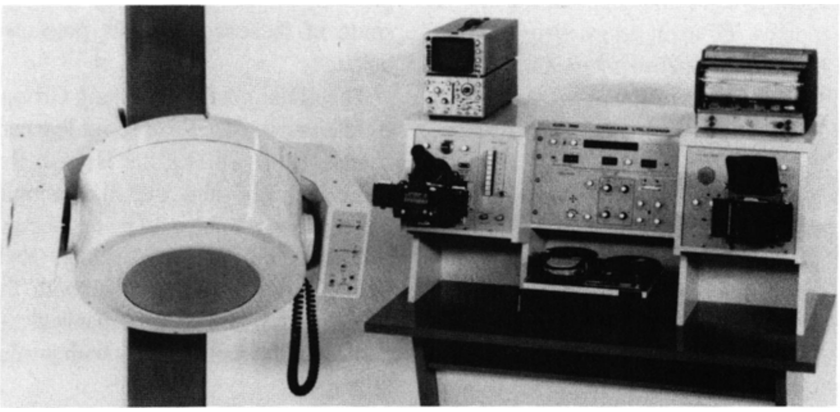

FIG. 1. Early large field of view scintillation camera which used delay line electronics. Note peripherals: videotape recorder, motorized 35-mm camera, Polaroid camera, and dualpen-chart recorder.

camera design has been to improve the contrast in images so that the best spatial resolution is attainable. The single significant component of noise that leads to a reduction in contrast is scattered radiation entering the photopeak window. In 1973, Beck (*3*) suggested that there is useful information contained in the scatter spectrum. The concept outlined by Beck lay dormant until digital technology had advanced sufficiently for the idea to reach fruition. In 1988, Siemens introduced the Weighted Average Module (WAM) that has the effect of applying an energy-dependent filtering kernel on the incoming data in real time (*4*). At much the same time, Gagnon described a technique for utilizing the full-energy spectrum of the acquired data (*5*), but this particular technique can only be applied after the fact and the system has not become available commercially. The effect of both systems is to decrease the scatter component thereby improving contrast and this is especially demonstrable with multiple energy radionuclides such as gallium-67. The effect is less dramatic for technetium-99m and thallium-201.

Computers have shown a dramatic improvement over the past 20 years. The first Gamma-11 system from Digital Equipment Corporation (DEC) had a 64K byte RAM memory, two removable discs each of 2.5M byte capacity, used a storage oscilloscope for the display, and used stand-alone software (no operating system) that was loaded from thirteen paper tapes. In contrast to this, the descendent of that original DEC system has 4M bytes of RAM memory, Winchester discs of 300 or more M byte capacity, a color video monitor, and uses a multi-user, multi-tasking operating system (TSX+). The speed of the CPU has increased by several orders of magnitude.

Despite this dramatic improvement in performance, the cost of computers has remained remarkably stable. The increased performance has not been matched by an equivalent increase in price. At the same time, the camera manufacturers have realized that a significant part of their market share was dependent upon the computer portion of the total system. To gain control of that market share, most manufacturers now offer integrated camera/computer systems so that the line of demarcation between camera operation and computer analysis is a lot less well defined.

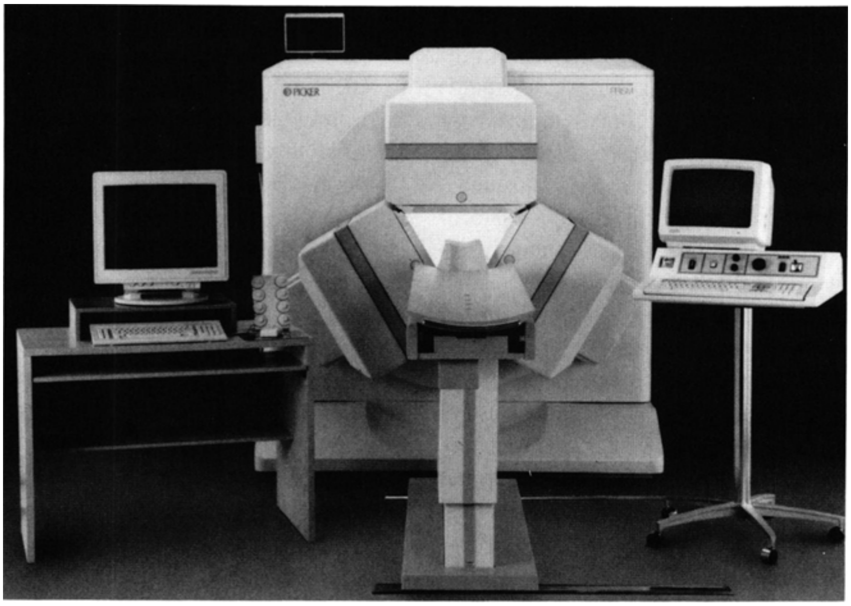

FIG. 2. Modern three-head tomographic camera system. On left is shown a video display monitor for workstation analysis.

The move towards greater computerization of scintillation cameras is hardly surprising when viewed within the context of the application of digital technology in all facets of life. However, in the early 1970s, the justification for a computer was based almost exclusively upon the need to collect data from dynamic studies. The development of gated cardiac studies (*6*) changed that situation dramatically because such studies would not be possible by any other means.

Although some forms of tomography were developed using rectilinear scanners (*7,8*), it was the introduction of the rotating camera technology (*9*) that led to the proliferation of single-photon emission computed tomography (SPECT) systems. Like gated cardiac studies, SPECT would not be possible without the availability of suitably programmed nuclear medicine computers.

It is of some interest to note that despite the heavy emphasis placed on SPECT technology in the literature, it still has not achieved widespread routine acceptance. One figure quoted by an industry representative is that 90% of all camera systems sold include SPECT capability, but only ~ 5% of such systems are used for routine SPECT. The major problem is that the relatively small improvements in clinical diagnosis achieved by SPECT are more than offset by the heavier demand for quality control; the extra time involved in data acquisition, reconstruction and analysis; and the superior interpretation skils demanded of the clinician.

Despite these sobering statistics, a number of manufacturers now offer very specialized tomographic units with either multiple detectors (Fig. 2) or ring detectors. Such specialized systems may find a place in large academic institutions although one recent analysis made in Canada reveals that to justify a triple detector system one would need to do in excess of 16 patients per day (Carr T, *private communication*, 1989). Quite apart from the logistics of fitting that work load into a normal working day, one would have to question the source of so many patients when the demand is presently so low.

Figure 2 also shows the newer developments in computer technology in which high speed reduced instruction set computers (RISC) are replacing the more standard display processors that previously have been used on nuclear medicine computers. These workstations are based on the UNIX, platform which implies a multi-tasking, multi-user system that is "open" in the sense that a source code can be readily transported between systems. Most manufacturers who have chosen this route of development have also adopted X-windows as the user interface.

Another parameter that will impact upon the use of computers is the greater realization that software can "break down" and faults can occur. The use of computers in medical systems is not without risk as has been tragically demonstrated by the overexposure of patients undergoing radiotherapy. These problems have not escaped the attention of the regulatory agencies, and, in the U.S., the Food and Drug Administration has established a program for the validation, acceptance, and quality asssurance of computer software used in medical systems. Presently, the degree of control over nuclear medicine software remains fairly loose on the basis that there is a human interface (the clinician) between the computer analysis and the diagnostic decision. This situation may change as greater emphasis is placed upon the use of knowledge-based systems (KBS) or artifical intelligence (AI) to provide a diagnostic optimization of the computer analysis.

In Europe, the COST-B2 project on Quality Assurance of Nuclear Medicine Software under the aegis of the Commission of European Communities is working towards similar objectives. In this case, however, it is the nuclear medicine community that is developing its own quality assurance program, working in cooperation with industry to ensure quality care.

In a review of this nature, it is natural to reflect upon the principal activity of nuclear medicine and to focus upon the scintillation camera/computer system. Computers have been applied to many other facets of nuclear medicine. For some time, PC-based systems have been available for tracking radiopharmaceuticals, and the records produced by such systems fulfill the Nuclear Regulatory Comission requirements. Systems for patient scheduling and accounting functions are much more common—particularly in larger departments attached to departments of radiology. Another development has been the use of widespread computer networks for electronic conferencing and electronic mail. Academic computers at thousands of universities are connected by a number of networks that collectively form The Matrix (*10,11*). One example of the value of these networks is to note that much of the data gathering and discussion related to the COST-B2 project mentioned above has been conducted via electronic mail. Collaboration of this magnitude would be considerably delayed if reliance had to be placed upon the normal postal services.

Nuclear medicine has witnessed some profound developments during the past 20 years. Its demise has been forecast several times as new and emerging technologies such as the computed tomography (CT) scanner and magnetic resonance imaging (MRI) gain acceptance. Despite such portents of gloom, nuclear medicine has managed, to not only survive, but to thrive. This resilience has been due in large part to the development of new and exciting radiopharmaceuticals and to the constant evolution of better instrumentation. Nuclear medicine remains a small part of the diagnostic process, but it continues to be an exciting field of endeavor with change and improvement being the one constant factor.

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