opponents, who are particularly strong in some regions. "The idea of a single federal site is very palatable," Dr. Gershey said. "I cannot see that this is a regional problem. It is easier to think about it globally, and it might be easier to find a single site."

Stanley J. Goldsmith, MD, clinical director of nuclear medicine, Memorial Sloan-Kettering Cancer Center, said that this whole process of having to store LLRW on-site "is a great disappointment in terms of the states' repsonse to the problem. It is a disservice to the community that uses radioactive material and the community that benefits from its use. Nevertheless, the biggest impact is on biomedical investigators." Furthermore, the controversy "helps to poison the emotional atmosphere against radioactive material."

Congressional Members Take Action

Yet the Barnwell closure may have increased the pressure to open the Ward Valley, CA site and other LLRW sites. Congressional members from outside California stepped into the act first with letters to the Clinton Administration. Rep. John Dingell (D-MI), chair of the Committee on Energy and Commerce, wrote that the Department of Interior's delay in transferring the Ward Valley land to the state of California was "troubling," and the federal government should not impede federal law that enjoins states to dispose of their own LLRW. At least three other Congress members have voiced similar admonishment.

Among them, Sen. J. Bennett Johnston (D-LA) has gone further, introducing a bill, S. 2151, "The Ward Valley Transfer Act," which he plans to move on once Los Angeles County Superior Court Judge Robert O'Brien rules on all pending litigation challenging the site's license. The bill would force Interior to make the land sale.

Interior Secretary Bruce Babbitt has delayed the land transfer until there are further hearings on the site's suitability, especially to answer concerns of the "Wilshire Reports," unofficial studies of Ward Valley's hydrogeology. A Needles, CA meeting, July 7-9, of sixteen scientists appointed by Sec. Babbitt to study these questions did not resolve the dilemma, but the final report on these environmental issues is due by the end of the year.

After the Barnwell closure, the eight states of the Northwestern Compact and four states of the Rocky mountain will continue using the Richland, Washington site. But other states, such as the Southwest Compact, the Northeast Compact, and the Central Compact, etc., are on their own. "We will have about 200 individual storage sites—hospitals, industries, utilities," said Doug Eldridge, general counsel for the New York Siting Commission. New York is not affiliated with a compact. "There are some bills in the legislature, but they do not appear to offer any immediate help. Intermediate storage will not be on-line until the end of the decade." In the meantime, generators will have to spend extra dollars for temporary storage.

Lantz Miller

COMMENTARY

EIGHT YEARS' EXPERIENCE WITH A FILMLESS ALL-DIGITAL NUCLEAR MEDICINE DEPARTMENT

Gerald M. Kolodny, MD

THE NUCLEAR MEDICINE division of our department of radiology has been an all-digital, filmless, imaging division since 1986, perhaps the longest continuous experience with an entirely filmless imaging department using digital images from multiple vendor image acquisition equipment. What principles have we learned from eight years of a picture archiving and communication system (PACS) environment? The answer deserves our rationale for PACS development; a description of our nuclear medicine PACS; enumeration of the advantages of a filmless department; and a description of the principles that should apply to widen PACS application. This experience can serve as a useful model in other departments considering a PACS program.

Digital Requirements

There are four major considerations when analyzing the design requirements of PACS: acquisition, networking, display, and storage. To garner the economic advantages of an all-digital environment, any PACS system proposed must use software and hardware that is widely available, and thus can spread its development and manufacturing costs over a wider market than medical imaging.

The display must equal or surpass film technology for it to be acceptable in the routine interpretation of all imaging studies. While we routinely use 512 x 512 video frame grabber images of chest x-rays to accompany our lung scans sent by modem, these images can only be used to diagnose gross pulmonary and cardiac pathology. Although 2000 x 2000 displays may be adequate for some applications, several studies have shown that to be certain that one is observing all possible abnormalities that would be visible on a bone or chest x-ray film study, resolution must be at least 4000 x 4000 pixels. To improve on film, the display must be able to easily accommodate changes in gray scale and background subtraction as well as review cines. Moreover, it must have the same capabilities of reviewing multiple films such as provided by current banks of viewboxes. Any changes in standard radiology practice which result in more radiologist time (such as zooming and keyboard manipulation) will not be accepted. Because of these display requirements, and the necessity to use current widely available standard technology, for cost considerations, the display of standard x-ray examinations should probably only be considered at the present time for research and special application purposes.

The second consideration, archiving, also limits the use of standard x-ray examinations in a PACS design. A database of at least a million studies, on rapidly accessible optical disc media of many terabytes, is necessary when considering storage for all the imaging studies of a median-sized hospital (350 beds). Optical storage of this magnitude does not exist today in a cost-effective package. Although newer technologies (e.g., helical recording magnetic tape systems) may permit storage of this magnitude, the lack of suitable software for databases and study transfer currently limits the applicability of these alternative media.

The third factor is networking and the communication band-width necessary between acquisition, display, and storage. A simple analysis of network and computer bus speeds necessary to access and display 10 routine chest x-ray examinations simultaneously, at the resolution and gray scale necessary (4000 x 4000; 16 bits deep), rapidly shows that these channels must operate at hundreds of megabits per second, far higher than current cost-effective technologies.

Finally, one must consider digital acquisition of x-ray images. There is currently no commercially available technology that can acquire x-ray images at the resolution and gray scale necessary within the acceptable time of current film-based technology. Although film can be scanned with a laser beam, the additional time and cost hardly contribute to the effectiveness of a digital department.

Although the display, storage, networking, and acquisition requirements for a completely digital radiology department are not currently available, the first three are actively being developed by many commercial sources for much wider markets than radiology. The wise counsel for the radiology community appears to be to wait patiently for these sources to rise to the need. In 1982, when we started developing our all-digital nuclear medicine department, we were at the technology's cutting edge. Not until 1986 did developments in optical disc technology finally make PACS a cost-effective and viable alternative for the low-resolution images used in nuclear medicine. As SPECT and multiple-head cameras have increased the display and storage requirements in nuclear medicine, technological development has kept pace with our requirements.

The fourth requirement of digital acquisition of x-ray images is, however, a unique problem. Thus, any radiology department's research program done in PACS should focus on this unique requirement for PACS. Nobody else appears likely to do it, whereas other groups will solve the other requirements.

Although technology has not yet advanced to the point where an all-digital environment is possible in an acceptable format for routine x-ray studies, there has been significant progress in displays, networking, and archiving since we first implemented PACS for the low-resolution images of nuclear medicine in 1986. The complete development of routine x-ray images in an all-digital format will depend not only on commercial developments for wider markets but on the radiology community's own development of digital x-ray acquisition of these studies. It is in this area of digital acquisition of x-ray studies that sponsored radiology research will be necessary before a truly acceptable and complete digital radiology department will be possible.

In our experience—over eight years with a fully operational, completely filmless, nuclear medicine department—the user interface is as important, if no more so, as the hardware implementation. Digital imaging has no advantage if it does not save the radiologist time and if it is so cumbersome to use that the radiologist is frustrated and cannot improve diagnostic quality. One cannot just hardware-link some acquisition stations with an ethernet and call it a PACS (as some nuclear medicine camera vendors commonly do).

Nuclear Medicine PACS: Display Station

Our filmless, all-digital nuclear medicine department (Figure 1) is built around a series of four PC-based networked image display workstations (Imagecenter, Sudbury Systems, Inc.) running in a Windows NT environment. An essential principle should be emphasized at this point. The studies are not displayed and analyzed by the physicians on an auxiliary camera display station. They are completely removed to a separate networked PACS system. There are several reasons that this is necessary in any PACS system. Use of the camera acquisition computer for functions other than acquisition slows down or limits the acquisition functions. (One does not get something for nothing.) The acquisition computer software has been optimized for acquisition, with very little consideration given to limiting its functions and suitability for physician display and interpretation. It is not possible to combine images from different cameras (e.g., if delayed views are necessary) into a single study using a single camera vendor station hooked to an acquisition computer. Finally, there is no way to access the central data base and archive many tens of thousands of studies, or the RIS, HIS, teleradiology, or reporting system, from an acquisition computer auxiliary display station.

Our original PACS system used a 512 x 512 display. Although this was adequate to display a single planar nuclear medicine study, it required a second display station to observe additional SPECT views or to compare the current study

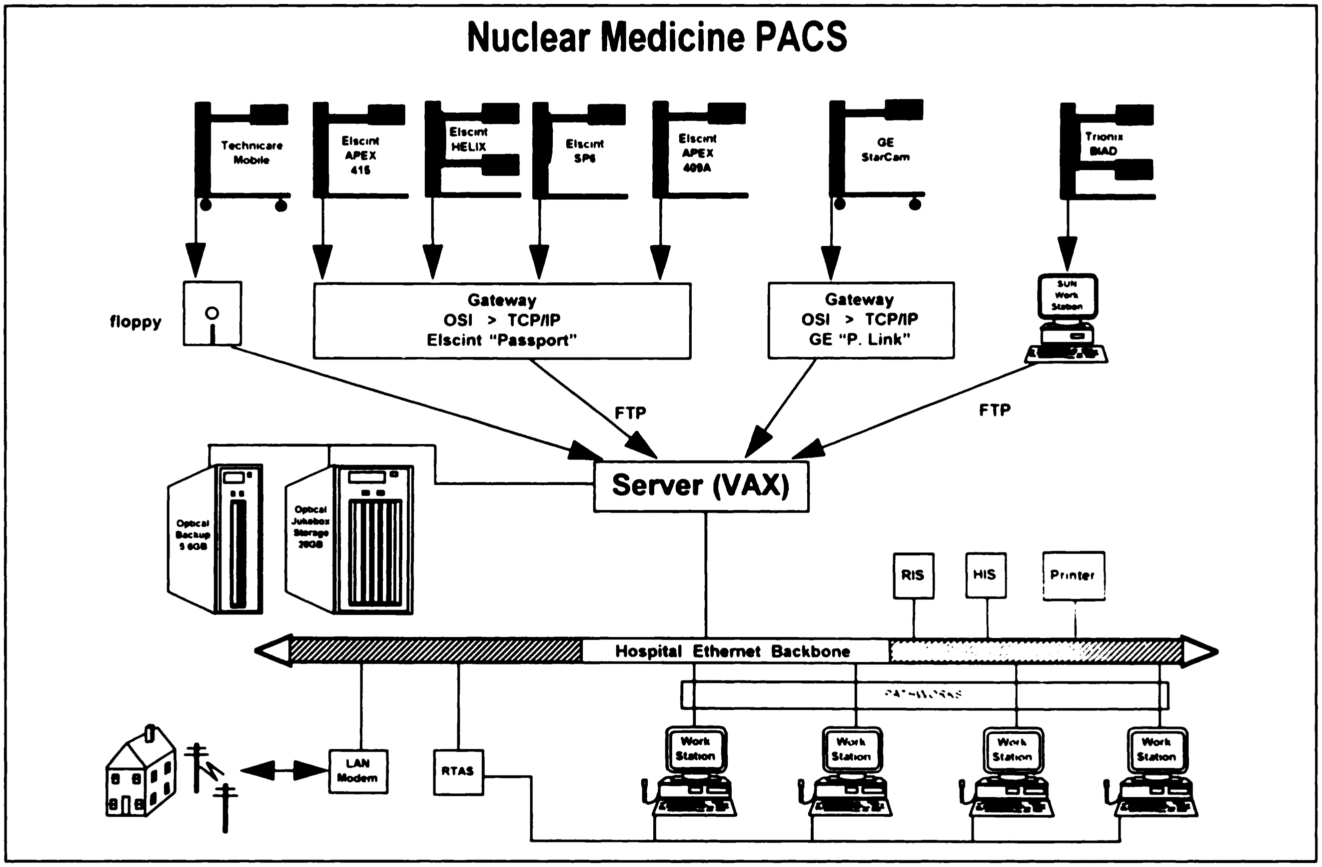

Figure 1. All-digital nuclear medicine department. Studies acquired on our seven nuclear medicine cameras are transferred to the system server through either the acquisition computer, gateways, or floppy disc. Studies are archived on a 28 GB optical disc storage module. Study images are displayed on one of three 1024 X 1280 pixel workstations that communicate with the server, RIS, HIS, printer, and reporting system, through the hospital ethernet backbone.

with a previous study. Our current workstations permit viewing a full 1024 x 1024 pixels, 16 bits deep, allowing a side-by-side comparison of the current study with three previous studies, all on the same display. Instead of two or more separate computer workstations, as our original PACS needed, we can use one large screen display on a single computer workstation. On the side of the main 1024 x 1024 display is an additional one of 156 x 156 pixels that can display in a preview area up to 12 minified studies, which can be individually "dragged" into the main display area. When a study is selected from the database, all the previous comparable studies on the same patient are automatically fetched from the database and put into the preview area.

In our original PACS system, separate terminals were used for the RIS, HIS, and reporting system (RTAS). The current workstation has windows into the department nuclear medicine information system, the hospital information system, and the department radiology reporting system. Although terminals are not simultaneously open on all of these systems, all the corollary information from the RIS and HIS, including interpretations of previous studies, can be obtained by simple mouse clicks to bring up the appropriate window during an image review sessions. After selecting the dictation window, the study interpretation is dictated while one looks at and manipulates the study images. Selected at the time of dictation, images appear in TIFF format at the time of report editing and approval on the RIS and are also available over the hospital-wide network to referring clinicians.

The nuclear medicine physician can access studies for interpretation by any one or a combination of six fields: name, patient number, date, study labels #1 and 2, or as a teaching collection case. A search for studies is made on both the server and the optical disc database.

The workstation permits a full range of nuclear medicine processing, analysis, and display. It was specifically designed for ease of use by physicians with only limited training. For example, at any point, a key may be depressed to display help for the function key currently being used.

Study Transfer

A crucial component of a digital PACS system is the means to transfer studies from different acquisition computers to the PACS network containing the display stations and archive. The most sophisticated display station from one manufacturer is useless if there is no means to transfer studies to it from an acquisition computer made by another vendor. Since no department would want to restrict future gamma camera purchases to one vendor, some means has to be made for translating the formats of each acquisition computer to a standard format and then transferring standard format images to the display stations and permanent archive.

There are at least four levels of network communication necessary between gamma camera computers and the workstations supplied by PACS vendors. First there is the hardware link (e.g., ethernet). Next there is the software for transfer of files between computers (e.g., FTP, NFS). The third level is in the application software, principally database and handshake software. This third level is the most difficult to address presently due to lack of application software from the gamma camera vendors other than for transfers between their own computers. Finally, there is the actual image format. Although the Society of Nuclear Medicine has endorsed the Interfile file format, (UWOVAX,UWO.CA; directory 0000.nucmed.interfile), not all vendors have fully implemented conversion routines. Transfer would be simplified if all vendors provided Interfile format. However, the Interfile format does not by itself address concerns at the other three levels. The DICOM 3 standard seeks to define the entire communication process, but it is yet to be determined how useful this standard will be for nuclear medicine. Although many gamma camera vendors are now accepting the necessity for Interfile format, few have yet complied fully with the Interfile standard now available, and most departments will retain older cameras for many years before Interfile is firmly established.

In the earlier version of our PACS, we transferred studies from the acquisition computers to the networked display stations and archive using floppy disks as an intermediate medium. The floppy disks were written with software provided by the gamma camera vendor. They were then read into our display stations and both their file and image formats translated into a standard format with software provided by our PACS vendor. Using the Intel PC Link network, the studies could be transferred peer-to-peer to any other display station or the optical disk archive.

In the latest version of our PACS, studies are transferred from the nuclear medicine acquisition computers to the workstations by two methods. Gamma camera computers which use non-proprietary computers (e.g., VAX, SUN, MAC) can be networked directly to our VAX server (Digital Equipment Corp.), which is also networked to the workstations using Patchworks (DEC) networking software. Our Trionix BIAD SUN computer, for example, is directly networked to our server. Studies from cameras that use proprietary computers can be transferred via floppy disk. The workstations are able to read virtually all versions of all the manufacturers' floppy disks (and write many formats as well). Studies from our mobile Technicare gamma camera are transferred by floppy disk, because this 14-year old camera does not have networking capability. Recent versions of the proprietary General Electric and Elscint computers use the Intel PC Link network, so that in the case of these two gamma cameras, we have been able to construct a network solution using gateway PCs.

Theoretically, there are two options for the user to accomplish study transfer between the acquisition computer and the server. Either the technologist at the acquisition computer can *send* the study to the server, or the technologist at the workstation can *fetch* the study from the acquisition computer. Because the gamma camera manufacturers do not provide software access to their database, it is not possible to fetch a study from an acquisition computer. The most one can do is read the directory on the acquisition computer hard disk, assuming a standard computer, with standard software, and make a guess as to which file or files constitute the desired study. However, for a *send* from the acquisition computer, a database in the application software is available to aid in identifying the files to be sent. Thus, once a study is finished, the technologist *sends* the study from the acquisition computer to the server. Next, the technologist goes to the PACS workstation and requests a study for display by name, data, ID, or type of study. The server reads the headers on the files sent to the server and can select the study desired. From the Trionix SUN, the desired file, its number identified from the Trionix database, is sent by NFS protocol to the server. From the Elscint computers, using their Passport software, studies are sent to the server through their PC gateway, which runs under the OS/2 multitasking operating system. Studies are transferred from our Starcam GE computer by means of GE software, installed on our PC-based workstation, which can read the Starcam database from a PC. Thus, in this case, it is possible to *fetch* studies from the Starcam hard disk.

The networking between the various camera computers, gateways, the workstations, and the main 28GB optical disk archive as well as the 5GB backup optical drive is provided by a node established on the hospital-wide network. This same hospital network provides access to the HIS and RIS for our workstations. In the future, it will be a means for our clinician colleagues to access selected TIFF images of their patients' studies from any site with a PC or MAC on the hospital network backbone.

Archiving

After transfer is completed, the technologist accesses the study from the server using one of the networked workstations. There the study is annotated, the header data added from our nuclear medicine information system, collated with images of the same study that may have been acquired on other cameras, and written as a unique study to our 28 gigabyte optical disc archive.

Data is stored using a nondestructive compression algorithm. All studies are automatically backed up on a separate five gigabyte backup disc drive. Discs written on the backup drive can be mounted in the 28 gigabyte drive in time of need or can be accessed separately from the backup drive. The database, copies of which are maintained on each workstation, is also periodically copied to the optical disc. If the database on the magnetic winchester disc on one workstation is lost, it can be copied from another workstation, or the complete database can be reconstructed by a program that reads the headers on all studies off each optical disc platter within the 28 gigabyte jukebox (Laser Magnetics). Backup is also provided by the use of multiple workstations that can work independently.

Conferences, Hard Copy, and Modems Oncall

When we are asked to display studies at conferences, a simple laptop computer is carried to the conference and studies are readily displayed with gray scale enhancement and in cine mode. This has a significant positive effect on our clinician colleagues. If a hard copy of a study is desired by our colleagues, we print a paper copy using our networked printer (Codonics). In our original PACS, display stations were equipped with a modem and software that permitted our attending physicians to "take call" from home on weekends and nights. The hospital modem was present in one of the workstations, and studies could be sent or fetched from the hard disc on that workstation only. A LAN modem on our current PACS network now permits modem access to the complete archive database and to windows into the RIS and HIS. Using a standard PC with a SVGA display at home, most studies are sent in under one minute, using nondestructive compression and 1.4 kbits/sec communication speeds (with an effective speed on 20-22 kbits/sec). The full digital data is transferred, not a standard teleradiology film image using a frame grabber. Thus, a full range of processing power, including analysis programs, cines, etc., can be used by the attending physician receiving the study. By the use of a standard video frame grabber, we also send relevant x-ray images. As in any standard teleradiology frame grabber setup, although the resolution of such images is fairly low, they usually can provide sufficient corollary information to aid in the interpretation of the nuclear medicine study.

Advantages of PACS

In studies on the cost savings of an all-digital department, we found a savings of about $15,000/year for a department doing 8000 studies/year in comparison with a traditional analog department. As computer equipment costs have increased, even further savings can be expected. The increases in efficiency are seen in various aspects of the department. For the technologists, there are no repeat images because the films are too dark or too light. Time is not wasted in trying to find misfiled, lost, or missing studies. Comparison with prior studies is most efficient when the studies can be compared with the gray scale and background subtract set at equal levels and when two cines can be compared side-by-side. SPECT thallium exercise and redistribution studies are best compared side-by-side with modification of the background and gray scale to best bring out relevant lesions. Our display software has been optimized for the physician user, and we encourage our clinical colleagues to feel free to access studies on the patients.

PACS Principles

What principles we have learned should guide other departments considering PACS implementation. The first principle is that one should start by implementing the lowest resolution studies and then work up in steps to progressively higher resolution studies. This not only keeps pace with technology developments but gives a department experience in stepwise fashion. A second principle is to design a separate free-standing PACS system and not attempt to use acquisition computers for display, processing, and archiving. As explained above, the acquisition computer has significant limitations and has no facility for handling studies from other manufacturers' computers.

Each section of a radiology department should have its own free-standing mini-PACS system, which can be networked to permit department-wide access to any study. Several factors favor this design. First, any software or hardware problem with one mini-PACS does not effect the entire department. Second, the network demands are significantly reduced so that waiting time for disc access or network throughput of data does not make the system unacceptable. Disc access time for optical discs is slow, and if all the department data is put on a single jukebox optical system and if several studies are being accessed at the same time, there are considerable lag times to change discs. If only a single department section is reading and writing to an optical disc system, the disc accesses are likely being made most of the time from a current working disc rather than from different discs in the system. Third, each modality has its unique requirements for display and archive access that can be optimized in the software of its own dedicated workstations. Networking will then permit each department section to access the database of any other section's mini-PACS.

Data from acquisition computers must be transferred to the PACS system. In our experience, this step is one of the most difficult in PACS implementation, because of the acquisition-computer vendors' inherent lack of cooperation and interest. While they pay lip service to standards, and glossy advertisements extol the virtues of interconnection, the vendors have not yet successfully implemented their schemes for interconnectability. Our experience is that they fall far short of what is needed, and none will give access to their software source code to make perfectly seamless data transfers and allow PACS access to their database. Most threaten to cut off service contracts if an attempt is made to enter their hardware or software. Although interconnectability is claimed, it is, in almost all cases (realistically), interconnectability only to computers from the same manufacturer.

It is not sufficient for a salesman to promise "ethernet," "TCPIP," "FTP," "DICOM," or any of a number of other acronyms. Too often, these fall short of the needs of a routine working PACS environment, and what the purchaser must have at this time is accessibility for software and hardware modification. For example, a vendor promised a gateway solution to transfer studies from its proprietary computer. The result was that each of the more than 16 images of a single study were transferred as 16 separate studies—satisfying their advertising of interconnectability, but hardly useful for a fully digital department that had to display the study completely and promptly for annotation, analysis, or interpretation. No effective database would want to handle 16 separate images, all with the same header data.

Ideally, gamma camera manufacturers should use hardware and software that is nonproprietary and "open." Unfortunately, manufacturers have invested in their own proprietary solutions which are not open. Databases, communication protocols, and application programs are often proprietary, even if the hardware is not. With this background, one should, as far as possible, design software for connectability independently from the manufacturer's acquisition computers. For standard computers (e.g., VAX, SUN, Macintosh), one should invoke standard software networking schemes to send VMS, UNIX, or MAC files from the computer and not attempt a design which depends on going into the manufacturer's application programs. In other cases, one needs programs that read floppy disc or tape output from proprietary computers. Occasionally, one can find a manufacturer that is willing to modify its application program, but too often at the next software release, the modification no longer works.

To partially remedy this situation, a department purchasing a new acquisition computer should insist not only that the application programs be suitably modified, but that all new software releases must maintain those modifcations. Second, regions of the source code dealing with the database and header information should be made available to the purchaser; or, alternatively, one should obtain a guarantee that timely, designed software changes will be made before and after equipment purchase. Third, the purchaser should retain the right to install networking software and hardware without voiding service contracts.

Conclusion

From our seven years' experience with a completely filmless, all-digital imaging department, we have gained insights that should be useful to others contemplating an all-digital radiology department. Our nuclear medicine PACS system provides network transfer of studies from our seven-image acquisition computers to three multiple-study display 1024 x 1280 pixel workstations. The workstations have windows into our HIS, RIS, and reporting system, allowing each workstation to be a single terminal workstation for all radiologist functions. Network modems permit remote access to the 28GB database. Issues of backup, conference presentation, networking, PACS advantages, and salient principles may help guide the development of PACS by others.

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NEWS BRIEFS

Decreasing the NRC Fee Burden

The struggle with onerous NRC fees recently found hope on two fronts. Although the agency is charged by law to recover all of its expenses from its users and licensees, sometimes the distribution of fees seems to fall on certain parts of this population to the point of harm.

First, this Spring, efforts to overturn a heavy fee from nonprofit educational institutions succeeded. In early 1993, upon an order by the U.S. Court of Appeals of D.C., the NRC had deleted a provision that exempted nonprofit educational institutions from annual fees (see *Newsline*, October 1993, p. 30N). Striking the exemption would have meant an extra $62,100 annually for 38 research reactors at 33 universities, many of which are strapped for funds. Closing reactors could have affected nuclear medicine research and training. After the NRC published the new fee schedules, several potentially affected institutions filed a petition protesting such a pending loss to the public good. After a few months' consideration of this petition and comments on the proposed fee, the NRC reinstated the exemption.

Also, late this Spring, the U.S. Senate and House addressed the problem of NRC's user fees, which directly affect nuclear medicine by creating a large expense for the agency's medical licensees. Since 1990, as the NRC budget has increased and the agency passed costs on to licensees, these fees have increased over 1,400 percent, adding burden to practitioners and patients. The nuclear medicine lobby brought the problem to Congress' attention this year, and both chambers in turn addressed it in their reports to the commission. The Senate report notes that "This escalation of fees has caused 2,700 licensees (including 500 medical licensees) to drop their licenses since 1991, directly affecting the health and well-being of those dependent on the medical services," and recommended that, to reduce costs, the NRC should turn over much of the regulation of materials licensees to the States.

"The accepted fact in Washington is that the best way to get an agency's attention is to have the committees that appropriate the money give them direction," said J. Michael Hall, director of legislative affairs, Joint Government Relations Office. If so, the commission has received the message from its highest authority that steep fees only hurt nuclear medicine and national health. ■

Nuclear Medicine World Congress Gears Up

The Sixth Congress of the World Federation of Nuclear Medicine and Biology, to be held in the Sydney Convention and Exhibition Center in Sydney, Australia, October 23-28, has received a tremendous response in its call for abstracts. Over 1,100 abstracts were submitted, 372 were selected for oral presentation in 64 sessions, and 590 will be displayed as posters. There will be 15 "State of the Art" review sessions, each with three speakers of international renown covering the status of major nuclear medicine topics; more controversial topics will be covered in the Symposia series. There have been 95 entries for the Iio Award, out of which five finalists will be narrowed to the single awardee, who will be introduced at the Closing Ceremony by SNM Past President Henry N. Wagner, Jr., MD. SNM President James J. Conway, MD, will conduct the "International Pediatric Challenge." Parties interested in attending the Congress should contact the Sixth World Congress of Nuclear Medicine and Biol-