Implementing HYBRID CT/PET

The University of Wisconsin Experience

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In Brief

In late 2001, the University of Wisconsin's Radiation Oncology Department installed one of the first radiotherapy-dedicated hybrid CT/PET scanners in the country. This scanner is shared between Radiation Oncology and Nuclear Medicine. In the last five years, the technology has proven valuable for diagnostic purposes and radiotherapy treatment planning. While the CT/PET acquisition benefited our hospital and patients, implementation of the new technology was not a seamless process. The adoption of the hybrid CT/PET posed challenges to our institution and, in particular, to the Radiation Oncology and Nuclear Medicine Departments that jointly share the equipment (see box, page 27).

Now, a few years after its acquisition, the CT/PET scanner plays a vital role in the functioning of both departments. This new technology has significantly altered the way we design radiation treatment plans for our cancer patients.

Going Hybrid

The University of Wisconsin has used a dedicated CT scanner to generate images for conformal, three-dimensional treatment planning since the early 1990s. By 2001, however, the equipment was becoming outdated. At the same time, the institution's Nuclear Medicine/Radiology Department was experiencing a backlog of cases for their solitary PET scanner. Hybrid CT/PET technology was becoming commercially available, and our institution was intrigued by the potential use of multi-modality fused images for radiotherapy treatment planning.

This confluence of interests led to the formation of a multidisciplinary working group consisting of representatives from Nuclear Medicine, Radiation Oncology, and hospital administration. The working group developed an effective communication and negotiation system to identify problems, agree on solutions, and work through implementation challenges in a time-efficient manner. In the end, this multidisciplinary team became the linchpin allowing successful implementation of the new CT/PET technology at the University of Wisconsin.

The work group's first task: looking at the option of co-registering images obtained from independent and separate PET and CT machines. Ultimately the team decided not to go this route because of substantial loss of anatomic accuracy in the fusion process. Both the Radiation Oncology and Nuclear Medicine/Radiology Departments understood the multiple challenges involved in multi-modality imaging, including the uncertainty and inconvenience of software fusion of separate PET and CT images and changes in patient positioning between different imaging modalities. In addition, staffing separate PET and CT machines would bring increased cost to the institution.

In the end, the working group concluded that a hybrid CT/PET scanner would most benefit the institution.

Selecting the New Technology

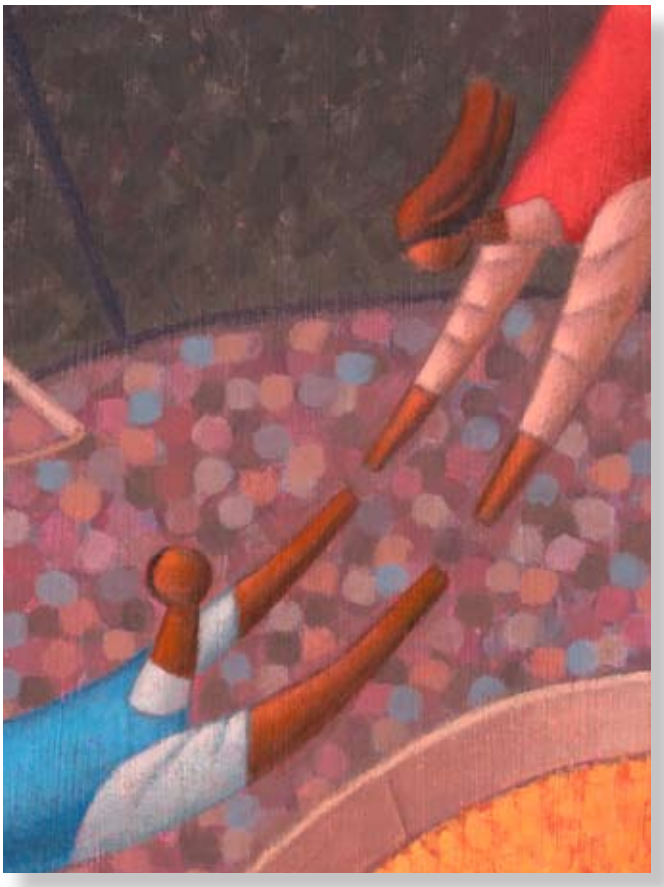
The working group then turned its attention to selecting the most appropriate equipment and began by carefully evaluating the available technology in terms of image quality, user-friendliness, flexibility of image acquisition, size of internal bore (through which the patient passes during imaging), and cost.

The working group came to the consensus that a General Electric (GE) hybrid CT/PET would best fit the needs and goals of the hospital and its departments. The decision was made based on the following factors:

- Prior experience with GE Medical products
- A reasonable bid
- Institutional contracting advantages
- Available software for integration with the existing treatment planning system
- Image transfer capability within the hospital-wide electronic image archiving system
- Bore size
- Image clarity
- Space considerations (specifically the need to fit a machine into very limited physical space in the Radiation Oncology Department)
- Ease of use.

Paying for the New Technology

The next challenge involved financing the CT/PET equipment. The initial cost of the new technology was too high for a single department's budget. (To give you an idea about the price tag of this new technology, today's CT/PET scanners cost between $1.7 and $1.9 million.) The multidisciplinary working group proved critical in this regard, spearheading the joint purchase of the CT/PET scanner by the Radiation Oncology and Nuclear Medicine/Radiology Departments. Fortunately, the Nuclear Medicine Department had an existing relationship with



Challenges Faced

- Selecting the best available CT/PET scanner to meet the needs of both our Radiation Oncology and Nuclear Medicine/Radiology Departments
- Funding the initial purchase of the device
- Physically accommodating the scanner in the Radiation Oncology Department
- Training nuclear medicine technicians and radiation therapists to use the new technology
- Scheduling use of the equipment between the two departments
- Interpreting the images the machine generates
- Ensuring adequate reimbursement
- Incorporating CT/PET images into our radiation treatment planning system
- Designing, funding, and implementing clinical protocols to test the scanner's capabilities.

GE Medical. As a result, the University of Wisconsin had an ongoing contractual agreement in place that provided for a substantial price advantage and ongoing software upgrades.

Because the CT/PET purchase was a shared acquisition of a very new technology, we were prepared for unexpected and expected problems to crop up. For example, the working group recognized that the CT/PET equipment would open up new research opportunities, leading to the generation of new intellectual property.

The University of Wisconsin has a long history of generating intellectual property. Historically, the institution's intellectual property is patented and often commercialized through an autonomous body, the Wisconsin Alumni Research Foundation.[1] The working group was able to enhance its leverage capability with GE by offering the company first right of refusal on any royalty-generating patents or licenses generated by the institution's research on the GE scanner, without creating any conflict of interest with the Wisconsin Alumni Research Foundation agreement.

Installation

The next decision the working group had to make was where to physically house the new equipment. The group recognized that the technology would be used for treatment planning for CT scans, as well as for CT/PET imaging. The decision was made to install the CT/PET scanner in the Radiation Oncology Department for the convenience of the cancer patients who would use the equipment most frequently. (Although patient convenience was the primary motivator, a secondary consideration was a lack of available space in the Nuclear Medicine/Radiology Department.)

Installing the equipment in the Radiation Oncology Department posed additional challenges. The hybrid CT/PET equipment would replace the institution's aging treatment planning CT scanner; however, the larger physical size of the new equipment meant that the existing room needed to be significantly remodeled. One wall was rebuilt, and the shielding requirements were enhanced to accommodate the higher energy (.511 MeV) irradiation.

The receipt, management, and administration of fluorodeoxyglucose (FDG) isotopes posed yet another set of challenges. While our experience with sealed and unsealed therapeutic sources, such as Cesium, Iridium, Iodine, and Samarium, helped us overcome some of these challenges, the acquisition of the hybrid CT/PET unit required additional staff training, as well as the remodeling of space to accommodate "hot" patients.

…STAFF FROM THESE TWO DIFFERENT "CULTURES" DIFFERED IN THEIR VIEWS ABOUT THE "CORRECT" WAY TO POSITION PATIENTS.

Innovative Solutions to New Challenges

Once installation was complete, the working group became aware of several issues that had not been thoroughly considered or adequately planned for prior to acquisition of the CT/PET hybrid scanner.

For example, the small size of the PET bore proved challenging, especially when using treatment-planning immobilization and localization devices, such as custom molds and wing boards. The Radiation Oncology and Nuclear Medicine/Radiology Departments experienced a "cultural barrier." In Nuclear Medicine, the scan acquisition is a one-time event, with very limited considerations regarding patient positioning. In Radiation Oncology, immobilization devices are created for each patient and used during treatment-planning imaging. The same devices are also used during daily treatment delivery to minimize patient positional differences over a period of many weeks. The barrier: staff from these two different "cultures" differed in their views about the "correct" way to position patients. Staff was able to solve this practical problem through discussion and mutual education.

In certain cases, the size of these treatment-planning immobilization and localization devices prevented the patient from passing through the PET bore. As a result, staff had to think "outside the box" to generate creative solutions. Take, for example, extracranial stereotactic radiotherapy treatment planning, which sometimes requires large whole-body molds to minimize respiratory motion. Unfortunately, the shoulder portion of these whole-body molds did not fit through the PET bore of the new equipment. Our solution was to adopt three-quarter-body molds that cover the lower extremities, abdomen, and most of the thorax, yet are still capable of limiting respiratory motion.

Another area where we had to make changes concerned frog-leg posturing for inguinal region treatments, which limits passage through the PET bore. We devised and used a posture in which the patient's legs are less flexed and hips are less externally rotated. Although not always ideal, this posture was an adequate compromise

The CT/PET scanner is located in the University of Wisconsin's Radiation Oncology Department. Pictured from left to right are the radiation therapists who operate the new technology: Eric Wevley, Melodie Corcoran, Stephanie Olson, Mary Burkhamer (radiation therapist supervisor), Yvonne Pola (clinic manager), and Dan Steinhoff.

15 Tips for Purchasing and Implementing New Technology or Equipment

1. Organize a working group comprised of key stakeholders to lead the effort and be responsible for decision making.

2. Define goals in a cooperative manner and identify the most appropriate technology or equipment to support those goals.

3. Choose the specific technology or equipment that best meets institutional and departmental needs.

4. Before purchase, leverage any institutional advantages with the vendor of the new technology or equipment.

5. Review all prior contracts that may potentially impact the purchase of the new technology or equipment.

6. Review the physical plant, including floor space, and know exactly how the new technology or equipment will affect this area.

7. Know what additional training is required to implement the new technology or work the new equipment, and ensure staff receives the training promptly and safely.

8. Understand that even with meticulous planning and preparation, unexpected issues and problems will likely arise during and after implementation of the new technology or equipment.

9. Be prepared for change and create ingenious solutions to ensure the new technology or equipment is integrated successfully into existing programs and services.

10. Do not reinvent the wheel. Instead look for pre-existing institutional solutions or processes that can be adapted to work with the new technology or equipment.

11. Understand that scheduling is a critical factor to success when departments or service lines are "sharing" the new technology or equipment. Without cooperation by all involved parties, even the best-made plans can fail.

12. Take a look at how the new technology or equipment will affect patient flow. Improving the way patients are triaged improves efficiency.

13. Identify the role each department will play with regards to the new technology or equipment so that billing and reimbursement can be divided in an equitable manner.

14. Know the capabilities and limitations of the new equipment or technology.

15. Don't be afraid to break "new" ground in terms of applying the new equipment or technology.

for CT/PET scanning and daily radiation treatments.

We also had to adapt how we positioned patients for tangential breast irradiation because the laterally outstretched arm exceeded the PET bore diameter of the new equipment. We resolved this problem by re-engineering our immobilization devices and moving the hand-grip pegs on the wing boards closer to the body. The laterally displaced arm now comes much closer to the body, without sacrificing the ability to place lateral tangent breast or chest wall fields.

Staff Training

The purchase and implementation of any new technology usually requires staff training. In our case, the vendor (GE) initially trained our technicians and radiation therapists on the use of the hybrid CT/PET equipment. In subsequent years, experienced staff provided on-the-job training to newer staff. In the end, the training voluntarily provided by CT technicians from our institution's Nuclear Medicine/Radiology Department turned out to be the most useful.

For example, our in-house staff held training on the use of the CT contrast power injector and the optimization of CT resolution. Acquired at the same time as the CT/PET technology, the power injector administers IV contrast at a fast enough rate so that the waiting time between contrast administration and CT imaging is minimized. Our radiology technicians were able to train our CT/PET technicians on the technical and timing aspects of using the power injector. Furthermore, to improve the quality of the CT scans derived from the CT/PET scanner, radiology technicians imported their own CT protocols into our machine. This assistance proved invaluable in improving resolution to a level comparable with that of the diagnostic-quality CT scans performed in the Nuclear Medicine/Radiology Department.

A Team Effort

Since the CT/PET equipment was to be shared between Nuclear Medicine and Radiation Oncology, the issue of time division became important. The working group would need to develop a solution that provided both departments ample time for imaging and would not significantly affect the efficiency of patient care.

Some patients, particularly those receiving breast brachytherapy and fractionated stereotactic radiotherapy, have very specific needs in terms of scan timing. The treatment-planning CTs for these patients must be done the morning of their planned radiation procedures. At the same time, many of the Nuclear Medicine patients were nil per os (NPO) overnight and could not realistically wait until the afternoon for their imaging. Ultimately, the working group reached a compromise that allowed Radiation Oncology to use the scanner for the first hour of each morning, Nuclear Medicine for the remainder of the morning, and Radiation Oncology again for the rest of the day.

This compromise helped improve efficiency and morale in two important ways. First, both departments became mutually accepting of occasional "exceptions" to this schedule. Second, both departments worked hard to ensure staff prepared patients and charts before their

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allotted time began. As a result of these mutual efforts, the CT/PET equipment currently operates efficiently and cost-effectively, and periods of idleness are rare (see Table 1).

Working together, the Nuclear Medicine/Radiology and Radiation Oncology Departments decided to partition all patients into three categories based on whether they required:

1. A diagnostic PET scan (with low-dose transmission CT for attenuation-correction, and no diagnostic CT with contrast)
2. A diagnostic PET scan with a diagnostic CT (with CT contrast);
3. A PET scan with a treatment-planning CT (often with CT contrast).

This categorization system allowed the three departments to define the appropriate amount of time required for each patient and to schedule the required time. In addition, staff had ample time to properly prepare each patient for his or her scan. Patients who require administration of CT contrast, for example, have fasting requirements.

Open for Interpretation

Next, the working group had to deal with a myriad of challenges related to scan interpretation, billing, and reimbursement.

As a matter of routine practice, all diagnostic CTs had been performed in the Nuclear Medicine/Radiology Department and interpreted by diagnostic radiologists. Adoption of the hybrid CT/PET technology posed unique challenges now that the reading of CT images was not always a diagnostic function.

The working group quickly agreed that the Nuclear Medicine/Radiology Department would interpret all PET images—regardless of categorization. The Nuclear Medicine physicians would then correlate their findings with the registered CT images. The decision about who would read the CT component of the scan proved to be more contentious.

For category 2 patients (diagnostic PET and diagnostic CT), for example, there was little question that a formal "diagnostic CT read" was warranted. For category 1 patients, who undergo a diagnostic PET with a low dose, somewhat thick-slice, non-contrast CT (presumably of lower quality and lesser accuracy for diagnostic purposes), the working group questioned whether the CT was of good enough quality to be read and billed for by the diagnostic radiologists. Many category 3 patients, who undergo a thin slice, high-dose CT, often with contrast-enhancement, for radiotherapy treatment planning have already received separate diagnostic CT scans for cancer detection and staging. These diagnostic scans are usually performed within the preceding one to three weeks. The working group questioned the need to create another "billable event" for these category 3 patients.

After considerable discussion, the working group decided that all diagnostic CT scans would be read and interpreted by Radiology physicians. (These physicians are encouraged to correlate their findings with those of the Nuclear Medicine physicians.) The working group also decided that radiation oncologists would use the information from category 3 treatment-planning CTs as part of the radiotherapy treatment-planning process—a decision that mimics national standards. Finally, the working group decided that in certain situations and at the discretion of the ordering radiation oncologist, radiologists may deliver formal diagnostic reads. As always, PET data is incorporated into radiotherapy treatment planning after interpretation by the Nuclear Medicine physicians.

Once these decisions were made, the working group went on to tackle the next challenge: reimbursement.

Over the past several years, the use of PET imaging as part of the staging evaluation of a newly diagnosed cancer has been approved for increasingly more tumor sites. As a result, reimbursement for performing and interpreting PET scans has increased. Reimbursement for concomitant CT scans is a more complex issue, how-

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Table 1. Use of the CT/PET Equipment

Fiscal Year	Radiotherapy			Nuclear Medicine	Research Time In Hours	Total Hours Spent (Average Hours Per Day[Δ])
	Treatment Planning CT/PET Scans (hours)	Diagnostic CT/PET Scans (hours)	Treatment Scans Planning CT (hours)	CT/PET Scans (hours)		
2003	32 (48)*+	117 (175.5)*+	742 (1113)	497 (745.5)		2082 (8.3)
2004	32 (48)	82 (123)	864 (1296)	562 (843)	56	2366 (9.5)
2005	33 (49.5)	106 (159)	939 (1408.5)	560 (840)	119	2576 (10.3)

*Assuming 1.5 hours spent on scanner per patient. This time includes preparing the patient and his/her chart and conducting all scans requested.
+Estimated statistics.
ΔAssuming 250 work days per year.

ever, with payers offering little guidance on the issue.

After considerable discussion, the working group decided that the reimbursement methodology should mimic the method developed for interpreting the scans. In other words, the Nuclear Medicine/Radiology Department would bill for diagnosis and the Radiation Oncology Department would bill for radiotherapeutic treatment planning. This system identified departmental responsibilities, clarified reimbursement processes, and ensured that patients continued to receive the best possible care–without creating excessive billing for patients and third-party payers.

Radiotherapy Treatment Planning

The working group faced one last challenge: incorporating PET images from the CT/PET equipment into the radiotherapy treatment planning system. Before this issue could be resolved, the working group first had to understand the capabilities and limitations of the software accompanying the scanner. Armed with this knowledge, here's how the problem was solved.

First, we reformatted the activity scan generated by the machine into a standard uptake value (SUV) map. We then converted the map into a DICOM (Digital Imaging and Communications in Medicine) image. We established a DICOM interface on the CT/PET scanner, which allowed the PET images to be accessible on the radiotherapy treatment planning system. The Radiation Oncology Department was then able to overlay or "fuse" the PET images with their registered CT images. The fusion process allowed staff to evaluate both anatomic and functional data, resulting in the most accurate delineation of the tumor on the treatment planning system.

The utility of CT/PET in radiotherapy treatment planning has shown significant promise, but systematic evaluation regarding its impact on contouring gross tumor volumes (GTVs) has been limited. As a result, our cancer center initiated a retrospective, blinded study that compared CT-derived GTVs for lung and esophageal cancer to GTVs based on CT/PET planning imaging. We compared the CT-based GTVs with the CT/PET-based GTVs by means of a conformality index (the intersection of the two GTVs divided by their union). A conformality index of 1.00 would imply that the CT-based and the CT/PET-based GTVs were identical. A conformality index of 0.00 would mean there was no overlap at all between the two contoured tumor volumes.

We evaluated 14 patients with lung cancer and 16 patients with esophageal carcinoma. The mean conformality index for lung and esophageal cancer was 0.44 (range 0.00 to 0.70) and 0.46 (range 0.13 - to 0.80), respectively. These findings suggest that the use of CT/PET scanning in radiotherapy treatment planning significantly changes the design of GTVs in a large proportion of patients.[2] The study is now the basis for an ongoing prospective trial evaluating the use of CT/PET-based treatment plans for patients with esophageal cancer, lung cancer, cervical cancer, lymphoma, and head and neck cancer.

Although the process of incorporating hybrid CT/PET imaging into our hospital has posed many challenges, the process has also been rewarding. Based on our retrospective and preliminary prospective data, we are confident that CT/PET imaging will significantly improve our radiotherapy treatment planning. Our experience and the lessons we learned will hopefully help other institutions adopt this exciting and promising medical technology.

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