FUSION TECHNOLOGY TAKES DIAGNOSTIC IMAGING TO A NEW LEVEL

The latest techniques for combining imaging modalities such as PET and MR are a revolutionary advance that will bring major clinical, research and economic benefits, say medical imaging experts at a recent roundtable hosted by *Health Research & Innovation*

MEDICAL IMAGING is one of the most important tools for diagnosis and treatment of many diseases, including cancer, brain disorders and other chronic, debilitating illnesses.

Anatomical imaging, which includes computed tomography (CT) and magnetic resonance (MR) imaging, is used to guide and shape treatment plans. Functional or molecular imaging, such as positron emission tomography (PET), often plays a significant role in follow-up visits to see where treatment might need to be altered.

Until recently, patients would have to go to separate machines for these different types of images, which could require two appointments weeks or months apart, depending on wait times, thus delaying diagnosis. Now, innovative equipment is available that can take both MR and PET images at once, using what's known as fusion technology.

Dr. William Pavlosky (above) and Dr. Frank Prato of Lawson Health Research Institute are working with Canada's first MR/PET imaging machine at St. Joseph's Hospital in London, Ont.

At a recent roundtable discussion hosted by *Health Research & Innovation* in partnership with Siemens Canada, a group of diagnostic imaging researchers who are leading the way with fusion imaging in Canada called the latest generation of this technology a revolutionary advance. They said it will completely change how chronic-disease research is conducted, how healthcare dollars are allocated and, ultimately, dramatically improve how many patients are treated.

By combining MR and PET, diagnosticians can more accurately see what's going on inside the patient. This is because the two modalities are highly complementary, said Dr. William Pavlosky (MD), diagnostic radiologist and nuclear medicine specialist at St. Joseph's Health Care London and Lawson Health Research Institute in London, Ont. MR is particularly good at identifying exactly where a problem exists, but the detection sensitivity is relatively poor. PET provides extremely precise information on the molecular processes occurring in the tissues but is vague about their location. Combining the two modalities can provide detailed images of exactly what's going on in a specific location.

Dr. Frank S. Prato (PhD), imaging program leader and assistant scientific director at Lawson, elaborated: "There are huge differences in sensitivity between MR and PET. Most of the biomarkers that we will discover that are early indicators of the beginnings of a disease will be in low concentrations. MR will not be able to detect those, but with PET we can go in and see that the tissue is starting to change, even though the biomarker concentration is only one in a trillion. Very early on we can start implementing changes for treatment. But the compromise is that PET has very poor spatial localization. It's a conundrum in imaging."

THE EVOLUTION OF FUSION TECHNOLOGY

The only way to deal with this conundrum used to be to send the patient for separate MR and PET scans, and then a specialist with experience in both types of image modalities would read the two sets of images and consider them together — "fusing" the data mentally — to determine the diagnosis or course of treatment.

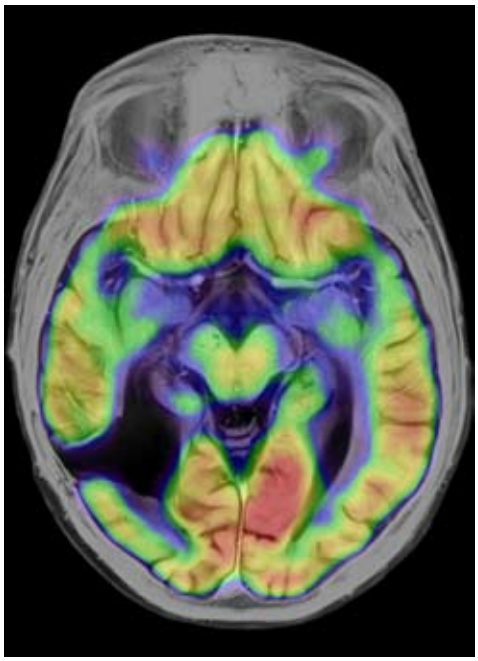
To help with this process, computer software was created so images could be overlapped more accurately on a screen but this often failed when the image content from the two imaging methods was very different. Seeing the benefit of combining these images, manufacturers developed machines that could take both a PET scan and a CT scan, one

after the other, in the same procedure and hence during a single patient visit.

The two sets of data from these scans would then be "co-registered" to produce one image that provided the diagnostician with the benefits of both modalities.

While co-registration of PET and CT data sets was a valuable advance in medical imaging, there are limitations to this approach. When two images are taken separately at different times, even within a few minutes of each other, they may not be properly superimposed due to heart and lung motion or the possibility that the patient moved by as little as one or two millimetres while lying on the bed between the sequential PET and CT data collection. This makes it difficult to have confidence that identical points in the patient's three-dimensional space are aligned, which is essential to ensure the correct diagnosis is achieved.

The MR/PET system comprises a magnetic resonance (MR) scanner and an integrated PET (positron emission tomography) detection system with an architecture that performs as one. This picture shows a lung imaging in a case of cancer.



Researchers see key clinical uses for MR/PET technology in the early detection of tumours and in therapy planning. This picture shows the image of a brain following successful tumour therapy.

Now, for the first time, MR/PET, the latest fusion technology, enables the MR and PET images to be taken at exactly the same time in the same machine.

"With MR/PET, we can do simultaneous data acquisitions, then the computer stitches it all together to create a whole-body image. In addition, we can go back and do a dedicated MR into any part of the body to get ancillary or additional information," said Dr. Pavlosky.

He and Dr. Prato have been working with Canada's first simultaneous, whole-body MR/PET machine, a Siemens Biograph mMR acquired by Lawson in partnership with St. Joseph's Health Care London and installed in early 2012 at St. Joseph's Hospital.

BENEFITS OF MR/PET TECHNOLOGY

The first and most practical benefit of MR/PET imaging is expediting procedures and improving the accuracy of diagnosis. Patients don't have to visit two machines for different scans and diagnosticians don't have to try to fuse images together.

The patient motion problem is reduced too. Simultaneous image capture means breathing and movement won't matter as much because images don't have to be matched up later.

"Also, the MR can do motion correction on the PET," noted Dr. Gerald Moran (PhD), research collaboration manager at Siemens Canada. "For example, I've seen images of a beating heart in MRI and a hazy PET image over the heart. You can motion-correct the heart in PET to see the ventricle moving very nicely when the two images are superimposed."

These machines are also invaluable when experts pursue imaging of events that may happen only once, said Dr. Bernd Wintersperger (MD), associate professor of radiology and section chief for cardiac imaging at University Health Network in Toronto. "Say you're looking for an ischemia on the heart muscle and need to perform pharmacological stress-testing. You don't want to stress the patient twice, but with these integrated machines you can do it simultaneously.

Dr. Bernd Wintersperger of University Health Network sees value for MR/PET technology in cardiac imaging.

"Or, in the case of epilepsy events, when a patient has an event, you can image brain morphology and function simultaneously and won't have an issue with reproducibility."

Fusion technology also has the potential to save the health-care system money. In oncology, for example, since it stages cancer more accurately than other imaging modalities, it could prevent unnecessary surgical costs when it demonstrates that a tumour is well advanced at the time of diagnosis, in which case there would be no point in the patient undergoing an intended curative surgery.

Fusion technology combining two imaging modalities allows researchers to see precisely how an intervention affects the cells and whether or not it's working to cure the disease.

NEW OPPORTUNITIES FOR RESEARCH

While MR/PET technology is still in its early days, perhaps its greatest potential is in research, as a learning tool, the roundtable participants said. Images can be used to monitor the effectiveness of new treatments first in animal trials and then in human trials. It allows researchers to see precisely how an intervention affects the cells and whether or not it's working to cure the disease. In essence, researchers are aiming to understand what causes disease and influences its development.

Over the past several decades, medical science has made great strides in reducing death rates from many acute conditions. Today, with an aging population and a growing incidence of chronic degenerative illness, "We need these technologies to start making discoveries that allow us to find some cures for these diseases," said Dr. Prato.

Dr. Wintersperger said UHN is also interested in integrated MR/PET technology to explore its uses in cardiovascular research. Such a technique will provide even more detailed insight into cardiac function, metabolism and disease mechanisms.

In cancer research, fusion imaging can help identify biomarkers to allow for more specific diagnosis of the type of cancer and if the cancer has spread. Applying imaging in this manner will help doctors develop more targeted treatment plans for cancer patients.

Fusion imaging will also advance brain research in a number of areas such as Alzheimer's, dementia, multiple sclerosis and stroke. The non-invasive nature of imaging allows for observation without biopsy, which is exceptionally challenging in the brain.

"For example, there's a 2011 study where Alzheimer's patients were put on a particular drug when they started to develop a little bit of cognitive impairment. They were on it for 60 weeks and then MR/PET was used to see that the burden of plaque in the brains in the treatment group was statistically less than in the placebo group," said Dr. Prato, adding that MR/PET is the best technology available for neurology right now.

In one-third of people who die with dementia, it's discovered on autopsy that they had the wrong diagnosis. "Essentially, we need these investigative tools in order to make the proper diagnosis first and foremost. We can then use them to deter-

A PICTURE OF COLLABORATION

At Lawson Health Research Institute, Dr. Pavlosky on the clinical side and Dr. Prato on the research side agree that the best — and fastest — way for institutions to acquire cutting-edge fusion technology is through partnerships between the two groups.

"Our philosophy at Lawson with implementing this equipment is to be an interface between the research institute and the hospital," said Dr. Prato. "We sometimes approach the hospital and say we are very interested in obtaining a new piece of leading-edge imaging equipment for research purposes. How about sharing the costs? With that kind of partnership, we both get to use the unit. When the two sides work together, new discoveries can be translated quickly and seamlessly into the hospital's clinical practice.

"Our experience shows that early on, the leading-edge technology is used a greater fraction of the time for patient-centred research, while later it's used mostly for patients to receive the latest proven technology to manage their disease without leaving the province."

To make this work, Dr. Pavlosky and Dr. Prato said there must be a commitment to collaboration between the groups and an end to attitudes of departmental silos. Hospital and research administrations need to determine together how to minimize the obstacles and optimize the process for translating discoveries into practice — or, more simply, work together on scheduling and maintenance.

Hospital-based research institutes and teaching hospitals have an ethical duty to do this, Dr. Prato added. "It's their responsibility to their patients to be doing research so the patients know that even in their own community there's work going on that's pushing the envelope in the hope of finding a cure for them and for people like them in the future."

And when discoveries are made, hospitals with research programs will begin attracting more top-level physicians and researchers, who will in turn improve the quality and standard of care for populations surrounding these research groups. It's a win-win situation for everyone involved.

mine whether current therapeutic regimens work or don't work," said Dr. Pavlosky.

BARRIERS TO IMPLEMENTATION

At this stage in the development of fusion imaging, there are two main challenges to seeing the technology fully embraced in hospitals and research centres across the country: lack of money and lack of suitably trained imaging experts.

There is limited funding for MR/PET across Canada, and none in Ontario. "We can't, at present, offer it as a standalone evaluation," said Dr. Pavlosky. "We have to piggyback it onto other evaluations that are being done to offset costs. The same thing happened with PET/CT. There's a significant lag between the initial evolution of a technology and the government's recognition of it."

Dr. Gerald Moran of Siemens Canada notes that with integrated MR/PET imaging, the MR can do motion correction on the PET.

Although high-tech imaging can be seen as expensive, added Dr. Prato, administrators should not frame it that way. "We know that in our jurisdiction, about 40% of individuals who have a PET/CT have their disease management changed. So if treating an individual for cancer costs $30,000 to $50,000 and with a $1,000 scan you can ensure 40% of patients are going to benefit, as opposed to being treated inappropriately, is it an expensive or inexpensive technology?" he asked.

When funding does become available, there may not be enough medical imaging specialists to keep up with the demand and continue to push MR/PET forward. Typically, specialists are trained in either functional/molecular or anatomical diagnostic imaging technologies; only a limited number of people are currently being trained in both.

"You would like to have someone who has had real education and experience in both of those imaging fields. But there are very few out there," said Dr. Pavlosky, who is one of the few medical imaging specialists that do have training and ongoing experience in both radiology (MR, CT) and nuclear medicine (PET) imaging.

MR/PET imaging machines can reduce wait times for patients and improve the accuracy of diagnosis.

"I see it as a question of sub-specialization versus convergence. As the amount of information in each of our fields continues to grow, we handle that sub-specialization. However, these fusion technologies are a form of convergence. They create special issues and we have to decide how to retrain people so we can carry on with these important new technologies," said Dr. Prato.

Dr. Wintersperger noted that many radiologists specialize in a certain organ system, but it will be important in the future for them to maintain some kind of general radiology skills and knowledge across imaging modalities such as MR and PET as well.

LOOKING AHEAD

Despite these challenges, there is no denying that fusion imaging is a vitally important medical technology with an exciting future.

"There will be continual development as it takes a while for these technologies to plateau. For example, the first commercial MR units came out in 1982 and we're still experiencing an evolution of its capability," said Dr. Prato. "With MR/PET we now have a very significant quantum leap in fusion technology that allows us to move forward in understanding what causes disease."

As fusion imaging continues to evolve, it offers Canadian hospitals and research institutes the opportunity to position themselves as innovative leaders in health research and care delivery. ■

Photos of doctors: Stephen Uhraney / Other images: Siemens

The information in this educational supplement is derived from a roundtable discussion that was hosted by *Health Research & Innovation* in partnership with Siemens Canada.

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