Clinical PET-MRI Moves Closer to Reality

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by Brendon Nafziger, Writer

Scientists across Europe have gotten one step closer to the dream of many imaging specialists: a clinical PET-MR machine.

Thanks to a European grant for the HYPERImage project, a consortium of scientists across Europe have worked with Philips to develop a proof-of-concept, pre-clinical combined MR-PET scanner that could one day lead to improved radiation therapy and cardiology treatments.

HYPERImage, funded by the European Union, leading research universities and Philips, has a budget of around 7 million euros to advance medical imaging.

While not functional yet, the experimental PET-MRI device does suggest that the technology in development works, and that the team has overcome some of the most important technical hurdles in combining two normally mutually hostile systems: state-of-the art time-of-flight PET with a powerful 3 Tesla MR magnet.

"They are two great technologies, but in principle they are very allergic to each other," Steve Klink, a spokesman for Philips, tells DOTmed News.

What the scientists did was create PET detectors "compatible with the strong magnetic fields associated with MR," he says, while also developing methods for PET attenuation correction, where scattering of gamma rays can create inaccurate readings.

This is hard for a number of reasons. First, magnetic fields can play havoc with PET's sensitive detectors.

"Magnetics distort electronics," Tobias Schaeffter, Ph.D., a professor of imaging sciences at King's College London who worked on the project and whose colleagues have been researching PET-MR devices for the last ten years, tells DOTmed News. This means common vacuum-based photomultiplier tubes, at the core of a PET machine, would be impossible to use, as they would get scrambled. That's why for the device, the scientists installed silicon photomultipliers with integrated digital read-out electronics, which are impervious to the magnetics.

But the interferences run both ways: the PET's electronics could also affect the MR device, creating misleading images.

"Any kind of electronics you put in an MR system could distort the static magnet field, and also introduce radio frequency artifacts, because it's very sensitive to any kind of signals coming from television and mobile stations, for instance," he says.

To solve this problem, they housed the digital PET modules inside a tiny Faraday cage, which traps the potentially distorting RF waves.

"There is some interference for which we have developed a mathematical model. We went through a number of iterations to have this model done and to use for the PET-MR design to minimize the interference," Schaeffter says.

The current version is a stacked system, consisting of the PET detector, crystals for gamma ray reading and integrated electronics, all caged inside an 8 cm long, 4 cm high box. The boxes can be scaled to increase power.

"A preclinical system uses 12 modules, and to go for a complete human system you need more for a ring," says Schaeffter.

Motion correction

One challenge of PET technology is photon attenuation, the intensity loss of gamma rays from the radioactive tracer (injected in the patient) while passing through tissue. The gamma rays get absorbed by different parts of the body at different rates, and this has to be corrected for when developing the image.

"You have a radioactive source inside the body, producing gamma rays with high energy," Schaeffter says. "Some of these gamma rays hitting on bones will be attenuated. So we have to put into the reconstruction process the different deterioration from the different organs. The lung has less deterioration than the bone, for instance," he adds.

Now, PET attenuation is often corrected for by using a CT scanner, which can compensate for the attenuation by helping to predict how much has occurred given the known attenuation rates of nearby tissue, and therefore the PET-CT modality has become a popular one. However, there is one drawback: PET is slow, taking anywhere from ten minutes to half an hour to acquire an image. While the patient lies under the scanner, the tumor can shift around from patient breathing, or from natural organ motion that happens in the body from the passage of gas or fluids. This movement can result in a blurred image. In addition, the tumor may move between areas with different PET attenuation that cannot readily be distinguished. And the CT scan, because it delivers an ionizing radiation dose, cannot be delivered continuously to provide completely accurate localization to correct for movement artifacts, according to Schaeffter.

But the team believes with MR, they can correct for both motion and attenuation at the same time: using time-of-flight PET combined with data reconstruction software running with the MR scan, they can, the idea goes, continuously monitor the patient during the time it takes for PET to work.

"We're able to derive motion-compensated attenuation corrections," says Schaeffter. "That means while we're doing a PET scan, we're also doing MR scanning, and then we can derive motion from MR scan, and we can use motion for two purposes: one to do proper attenuation correction, and two, to do motion-compensated PET reconstruction."

Clinical benefits

Though undoubtedly a technological achievement, what benefit would this bring to patients in the radiologist's office?

Schaeffter believes the combined MR-PET would have a number of clinical gains, from improved workflow to more precise heart-function tests and better guidance for cancer treatments.

For one, it could improve sensitivity by correcting for the above-mentioned motion blur. "By correcting for motion, you would get a sharper tumor," says Schaeffter. This could allow you to "detect smaller lesions in an earlier stage," he says.

Plus, PET and MRI can be combined for novel therapies. For instance, Schaeffter says scientists are working on PET agents that show regions in the body with hypoxia, or low oxygen. Tumors with low oxygen, he says, need higher doses of radiation therapy to fix. While the PET scan is being done, the MR scanner can also measure blood flow and determine if the tumor is highly vascularized, as these sorts of lesions can treated with separate drugs.

Together, these two modalities could also help with certain tests of heart strength and function. The MRI modality, Schaeffter says, is the most accurate one to assess heart muscle contractions, which can then be conducted at the same time as PET perfusion studies - to monitor how well the heart muscle is perfused. Although the two tests could be performed sequentially, by doing them at once, not only would doctors reduce workload, they could measure the related functions at the same time under the same stress conditions. This could give a more accurate assessment, Schaeffter suggests.

The future

Still, the device is some ways away from any real clinical applications, as the team has only just finished the proof-of-concept stage, showing the device does, in principle, work. Right now, the team is aiming to have a preclinical version ready for the next milestone, its first image, which they expect to have by the middle of next year.

"In the end, that's what counts," says Klink. "You have to show images."