

New scanner combines positron emission tomography and magnetic resonance imaging

With positron emission tomography (PET), doctors can look inside a patient's body and pinpoint hotspots of malign molecular activity. Secondary tumors, for example, show up as scattered pockets of hyperactive glucose consumption.

Perversely, the specificity that makes PET so revealing impairs its usefulness. Like isolated farmhouses you see at night through an airplane window, PET peaks appear against a dark, featureless background. To reliably associate the peaks with the right organ, doctors need a map of the patient's body.

Two three-dimensional imaging modalities can provide the requisite map: x-ray computer tomography (CT) and magnetic resonance imaging (MRI). Of the two, CT is easiest to integrate

Like other PET scanners, UCD's PET/MRI unit detects the photons that result when a positron, emitted by a radioactive nuclide, promptly meets an electron and annihilates itself and the electron. The radionuclide is incorporated into a tracer molecule, which is injected into the patient and provides the technique's molecular specificity.

The spatial information comes from the annihilation. At the time of their fatal encounter, neither lepton has much momentum. As a result, the two 511-keV photons fly off in almost opposite directions. At about 0.25° , the typical deviation from exact collinearity is small enough that PET can exploit coincidence to locate the tracers. PET detector elements are arranged in a ring centered on the patient. If two opposing detector elements detect 511-keV photons at the same time, the annihilation event, and therefore the tracer, must lie in between. Applying tomography algorithms to all valid coincidences yields a 3D PET map.

The first step in detection occurs when a 511-keV photon hits a scintillator crystal and produces optical photons. To convert the optical signal into an electronic signal, the UCD team uses avalanche photodiodes. APDs are a recent innovation. Each diode consists of a layer of silicon, a few hundred microns thick, across which a strong electric field is applied. When optical photons hit the silicon, they beget electron-hole pairs. The electric field accelerates the pairs, which slam into atoms, beget more pairs, and boost the electronic signal.

The MRI scanner's strong magnetic field barely deflects the pairs on their short trip through the silicon. However, the scanner's RF coil and

its rapidly changing gradient field both interfere with APD electronics. Shielding the electronics works to some extent, and could suffice for clinical applications, but placing a conductor inside the MRI scanner's active field of view risks introducing image artifacts.

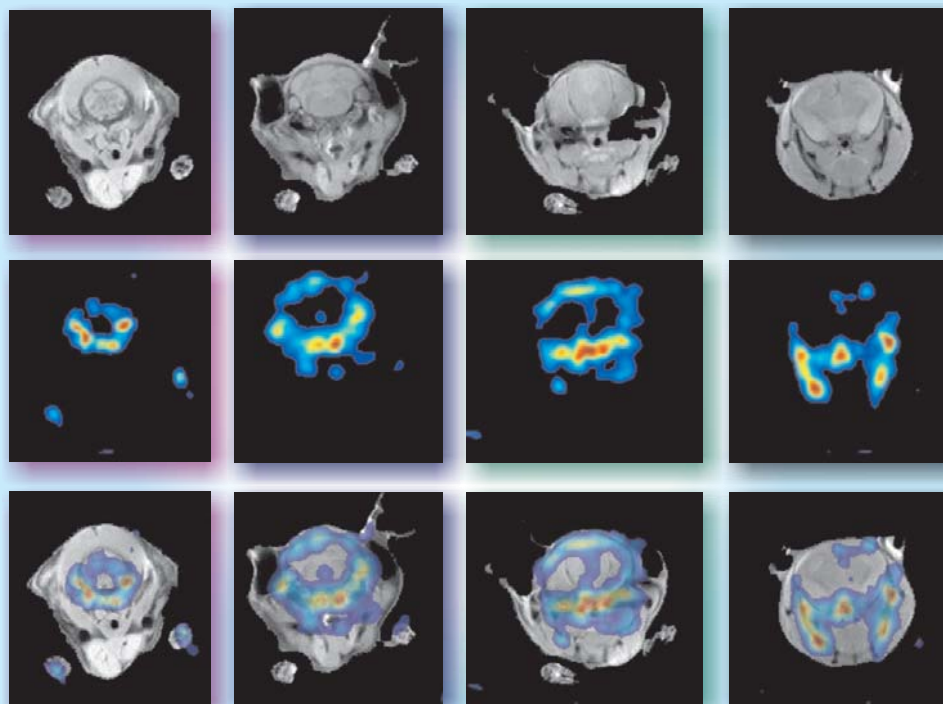
To avoid that problem, the UCD team separated the scintillator crystals from the APDs by means of optical fibers. In principle, the APDs could lie far outside the MR magnet, but the weak optical signals would peter out in the meters-long fibers that would be needed. Instead, the UCD team opted for short fibers that keep the APDs within the main MR magnet but out of range of the RF and gradient coils. That hybrid approach, Cherry believes, provides the sensitivity and fidelity for imaging biomolecular processes and their organ-scale consequences.

The accompanying figure shows coronal scans through the head of a mouse. MRI scans appear in the top row and show the brain, muscles, and other soft tissues. Simultaneous PET scans appear in the middle row. Here, the PET tracer is a simple fluorine-19 anion, which concentrates in the mouse's skeleton. The PET hotspots correspond to the skull, jaws, and forepaws. The bottom row shows the combination. Scaling up to fit humans shouldn't be a problem. "The design is very modular," says Cherry.

Charles Day

Reference

1. C. Catana et al., *J. Nucl. Med.* **47**, 1968 (2006).



with PET. Because CT and PET both rely on detecting high-energy photons—annihilation photons in the case of PET—their basic technologies are compatible. Nearly all the PET scanners on the market today are PET/CT units.

Combining PET and MRI is more challenging. MRI requires strong magnetic fields and intense RF pulses, yet it is susceptible to tiny inhomogeneities, which spawn image artifacts. For a PET/MRI unit to work, the PET scanner must endure the MRI scanner's extreme electromagnetic environment without compromising fidelity.

Achieving that feat is worthwhile for several reasons. On the clinical front, a PET/MRI unit would enhance the use of PET in diagnosing a number of diseases, especially those found in the brain and in the pelvic region, such as prostate cancer and ovarian cancer.

On the research front, PET could work in concert with targeted MRI contrast agents and MR spectroscopy. With that suite of techniques, researchers could monitor how drugs interact with their molecular targets and how the damaged organ heals.

Now a team led by Simon Cherry of the University of California, Davis, has taken a significant step toward those goals. Cherry, his grad student Ciprian Catana, and their collaborators have built a device that simultaneously images a mouse-sized animal in PET and MRI.¹