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### The Hyperimage Project

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The EU-funded HYPERImage research project aims to merge the concurrent PET and MR imaging techniques, with the goal of opening new fields in therapy planning, guidance and response monitoring. PET/CT scanners allow functional information such as glucose uptake rates derived from an FDG-PET scan to be co-registered with anatomical features in the CT images. However, because of MRI's superior soft tissue imaging capabilities and its ability to provide additional functional information, such as blood perfusion measurements, a combined PET/MR scanner could potentially be of even greater benefit than PET/CT. In addition, MRI's ability to capture the motion of internal organs could be used to enhance both the resolution and sensitivity of the PET images. However, concurrent clinical PET/MR scanners do not currently exist due to inherent incompatibilities between conventional PET detectors (photomultiplier tubes) and the high magnetic field strengths encountered in MR machines.

#### Can PET & MR be Compatible?

Getting an experimental MR-compatible PET detector to work inside an MR system was a key first step in developing this technology. Development of a solid-state PET detector that is not affected by the high magnetic field of the MR-scanner or by reception of the MR signal involved eliminating magnetic materials, such as nickel in electronic component housings, and screening of the entire detector in a Faraday cage to prevent the introduction of RF noise into the MR signal.

One of the first challenges is to assess how well the motion capture capabilities of MR imaging can improve PET images. PET's reliance on low-level radioactive decay events means that PET images typically take ten to twenty minutes to acquire. As a result, any movement of the target tissue, e.g. due to cardiac motion, blurs the PET image, leading to a loss of resolution.

The project will therefore investigate how motion information extracted from the MR images can be fed into the PET reconstruction software to 'deblur' the PET images.

As an extension of this technique, it may also be possible to use the MR-derived motion information to dynamically correct for PET attenuation. In oncology applications, this motion compensation may allow more reliable imaging of much smaller tumours and those located in regions with a significant amount of movement.

#### Improved Pharmacokinetics

PET/MR imaging may also provide better pharmacokinetic measurements than currently possible. Pharmacokinetic investigations to identify tumour activity involve the measurement of how fast a tracer is perfusing into tumour tissue, how much is actively transported into tumour cells and how fast it is removed from the blood stream. This requires a perfusion measurement, most easily accomplished with MRI, and a tracer uptake measurement performed with PET. Combining the complementary strengths of MRI and PET may thus improve the accuracy of pharmacokinetic investigations.

Quantifying the pharmacokinetics of PET tracers more accurately may allow clinicians to monitor a tumour's response to therapy more accurately, allowing smaller changes to be detected. This should in turn allow clinicians to more quickly identify whether a patient is responding to a particular chemotherapy regimen. This could also reduce the costs of developing new chemotherapy agents because fewer patients may be needed in phase three randomised trials to determine if one agent is better than another.

In cardiology, the simultaneous capture of MR-derived functional information such as cardiac wall motion and PET-derived information such as myocardial perfusion could improve the diagnosis of myocardial infarction. Since these tests are normally performed during an artificially induced stress test, the reaction of the patient is also highly variable from day to day and hour to hour. Once again, simultaneous capture of MR and PET images could overcome this variability.

#### The Way Ahead

The HYPERImage team is now focusing on finding ways to integrate a scaled-up detector into the bore of a wholebody MRI scanner. Scaling the detector area to the required size is not the major issue, since the planar nature of solidstate photomultipliers means that they can be tiled together to create large detector surfaces. The greater challenge will be positioning this detector into the MR machine's excitation coils without disturbing the coils' normal functioning. The approach currently being adopted is to split the MR scanner's RF and gradient coils to create the required space. On the software side, the major challenge will be the development of algorithms to extract accurate motion vector fields from the MR data and feed them through to the statistical PET reconstruction and PET attenuation correction processes.

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