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Multimodal Imaging

Multimodality imaging is widely considered to involve the incorporation of two or more imaging modalities, usually within the setting of a single examination using, for example, dual- or triple-labelled optical or nuclear medicine "reporter" agents or by performing ultrasound or optical studies within the MR, single-photon emission computed tomography (SPECT), or x-ray computed tomography (CT) environment.

Rapid Evolution a Hallmark

Clinically, the best example of multimodality imaging is now being seen in the rapid evolution of PET-SPECT and PETCT scanner hybrids. The PET modality has developed into perhaps the most used multimodal imaging method. The incorporation of PET into single, hybrid, and multimodality units to provide functional (typically from injected F-18DG studies) and anatomic information is becoming extremely popular, so much so that, for example, PET/CT hybrids can be found in outpatient screening centres located in shopping malls.

> **"MR-PET (or MRI/PET) is the future of multimodality medical imaging. Several prototypes are undergoing research and one institution – the Brookhaven National Laboratory – has announced licensing opportunities for a prototype device that it has developed"**

The role of any multimodal imaging approach should ideally provide the exact localisation, extent, and metabolic activity of the target tissue, yield the tissue flow and function or functional changes within the surrounding tissues, and in the process of imaging or screening, highlight any pathognomonic changes leading to eventual disease. Multimodal clinical NM, PET, and MRI techniques have, to date, fallen into the growing fields of molecular and functional imaging for primary-to-metastatic cancer screening of the body, neuro-assessment of gliomas, integrated stroke imaging exams, and functional neuroimaging exams.

In current medical imaging practice, image fusion has substantially expanded the scope of non-invasive exploration of the human body. Image fusion/co-registration can be performed intra-patient or extra-patient. Intra-patient image fusion is the true form of image co-registration and requires specially designed equipment that has dedicated instrumentation for each modality. The latter involves fusion of images with the help of mathematical algorithms and computational power. Such software- based fusion techniques are performed by identifying and aligning landmarks or fiducials. Image fusion extends exploration by combining details of anatomy with function captured using various cross-sectional modalities. Only instrumentation- based image fusion innovations are described here.

PET/CT and SPECT/CT

This multimodal imaging technique involving the combination of nuclear imaging and x-ray scanning is a fusion of anatomic and functional imaging. Pioneered at the University of San Francisco by Hasegawa et al., the first commercial designs were the Hawkeye SPECT/CT from GE in 1999. PET/CT hybrid scanners arrived on the market within the next three years, pioneered by researchers at the University of Pittsburgh. Co-registration of PET with CT enables anatomic localisation of F-18-FDG accumulation, thus improving specificity of lesion detection.

Further, the combination bypasses the need for photon attenuation correction owing to the differences in the energy spectra of X-rays and 511 keV gamma rays. Attenuation correction is performed through the formation of an attenuation map using the CT part of the instrument. In regular PET scans, attenuation correction is performed though a blank scan of the transmission source and the patient before administration of the radionuclide. Most marketed SPECT/CT scanners incorporate a dual head gamma camera coupled to two 64-slice CT equipment. PET/CT scanners have full ring PET modules and have up to 64 slice CT capacity. Sattler et al. (2010) estimated that PET/CT scanners have replaced 75 percent of all stand-alone PET systems installed in Europe.

MR-PET

MR-PET (or MRI/PET) is the future of multimodality medical imaging. Several prototypes are undergoing research and one institution – the Brookhaven National Laboratory – has announced licensing opportunities for a prototype device that it has developed. As discussed earlier, the PET detectors will have to be devoid of PMTs and will have to incorporate alternatives such as solid state technology. Incorporating PET cameras and MRI coils into the same gantry is the most prominent concern in developing a combined instrument. The prototype developed by Brookhaven National Laboratory involves a PET detector assembly concentric to MRI coils. The PET detector used is basically an LSO scintillator coupled with a Hamamatsu S8550 APD.

The design owes to the institution's RatCAP small animal scanner that is completely 3D and is used to image live rat brains. The RatCAP scanner also has an improved readout circuit (front end ASIC, preamplifier, and signal system) that produces less noise. Among the manufacturers of PET and MRI who have ventured into development of MR-PET machines are Siemens and Philips. Each of them has developed separate perspectives about the positioning of the PET camera module in relation to the MR coils. Siemens has developed a prototype in collaboration with researchers from the University of Tübingen and the University of Tennessee, which is undergoing trials in Germany. The prototype is very similar to the model available for licensing from Brookhaven National Laboratory. It uses APD as the workhorse and is being evaluated as a tool for brain imaging. Attenuation correction is performed on the basis of the MR image by identifying landmark regions.

Concluding Remarks

During the last decade, considerable progress has been made in the development of anatomical and functional imaging modalities and supportive software, leading to rapid and accurate data acquisition and analysis. This has enabled imaging to be used more broadly to aid diagnosis, identify disease stages and support treatment and patient monitoring. In many cases the price has decreased and accessibility has increased, facilitating the use of medical imaging as an integral tool in the physician's armory to detect and treat disease. In return technological breakthroughs have allowed surgeons to migrate towards less invasive medical procedures and early treatment intervention as multimodal systems and novel imaging agents enhance their ability to stratify patients through accurate and educated treatment decisions. New contrast agents, detectors and computer aided programs will guarantee this innovative market continues to meet the demands of the consumer helping to ensure the right treatment for the right patient.

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