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The evolving field of Hybrid Imaging in Cardiology

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Take Home Messages

- Hybrid imaging is a rapidly developing tool for the non-invasive assessment of coronary artery disease and coronary anomalies.
- This editorial outlines the new fusion imaging modalities available and the expanding range of clinical applications.
- Widespread uptake of this technology will depend on:
  a) Improving accessibility outside of research and academic centres.
  b) A larger body of research that can demonstrate clinical efficacy above and beyond current practice.
- Current limitations include high costs, limited familiarity with interpretation and high radiation doses for CTCA-FFR/MPI.

Introduction

The role of non-invasive testing within Cardiology continues to move apace. A rapid evolution in the technology available means we now have a greater number of tools to evaluate the heart. Advancements in hardware and software have improved the safety profile and the diagnostic accuracy of imaging modalities (1). Nowhere has this impact been felt more than in the assessment of patients with coronary artery disease.

Clinicians have long used multiple imaging methods to aggregate information on many aspects of cardiac disease. This would be followed by a mental fusion of the two results to better impact clinical outcomes. In the past few years, the advent of hybrid scanners has facilitated the composition of differing imaging modalities (2). The result is an exciting and rapidly developing field of hybrid imaging.

This article sets out to highlight the various hybrid imaging modalities available to us currently, the clinical applications for which they are employed, and finally the future prospects for this technology.

What is Hybrid Imaging?

Hybrid imaging is the fusion of two or more cardiac imaging techniques. With respect to coronary artery disease, this allows simultaneous assessment of the presence and physiological significance of coronary artery stenosis as well as the end-arterial effect on myocardial perfusion and contractility (3). This can also involve a single imaging method that combines structural and physiological parameters. An example is Computed Tomography Coronary Angiography with Fractional Flow Reserve (CTCA-FFR) and Computed Tomography (CT) perfusion imaging.

Hybrid scanners are able to combine CT with magnetic resonance imaging (MRI), single-photon emission computed tomography (SPECT) and positron emission tomography (PET) hardware (4). The development of solid-state semiconductor detectors allows shorter acquisition times, improving patient tolerance and reducing the total radiation dose (3). Patients will undergo one scan followed by an amalgamation of data, or sequential imaging with two different techniques.

Dedicated software enables 3D reconstruction and superimposition of perfusion data from SPECT imaging and coronary anatomy from CT. Newer reconstruction algorithms enhance SPECT/CT image quality and improve overall sensitivity (5). The ability to spatially superimpose images from differing scans while accounting for motion artefact, respiratory intrusion and fine morphological differences during gating is a remarkable yet crucial feature.

Current clinical applications

Coronary artery disease

The main area of additional benefit will be seen in the population with intermediate pretest probability for ischaemic heart disease. The combination of anatomical stenosis quantification and a functional assessment based on the identification of a myocardial perfusion deficit is a useful tool in determining the significance of a lesion. In a study by Danand and colleagues 252 patients with stable angina underwent combined CTCA and myocardial perfusion imaging (CTCA/SPECT) as well as invasive FFR (6).In two thirds of the multicentre trial, patients with intermediate pretest probability for coronary artery disease, hybrid imaging could be used as a reliable rule-in/rule out strategy for haemodynamically significant lesions.

A 2017 meta-analysis of 12 studies showed that hybrid imaging improved the diagnostic sensitivity for obstructive coronary lesions when compared to plain CTCA (7). However other studies have found CTCA/SPECT and PET to be just as good as invasive FFR in detecting myocardial ischaemia, but without any significant increase in diagnostic yield (8).

CT perfusion with CT FFR is already an established tool in assessing coronary lesions. Intravenous contrast injection during imaging not only opacifies the vessels to define obstructive lesions, but is also absorbed by the micro-capillary bed within the myocardium. Visual areas of low uptake correspond to myocardial hypoperfusion. The additional ability to physiologically classify the heamodynamic significance of a coronary stenosis makes this a very helpful triple-tool in the Cardiologist’s armoury.

A contemporary meta-analysis has supported the ability of this hybrid approach to improve the positive predictive value and specificity in identifying lesion-attributable ischaemia, when compared to plain CTCA (9,10). The main limitations to widespread use include the relatively large financial cost and the high radiation dose administered per scan.

Coronary anomalies

Hybrid imaging can provide additional value in the assessment of patients with rare coronary artery anomalies. The most recognised and well-described variant is anomalous coronary artery from the opposite sinus (ACAOS). It is associated with an increased risk of sudden cardiac death (11).

SPECT/CTCA and PET/CTCA are useful for simultaneously defining anatomy and detecting underlying myocardial ischaemia. A small study of 46 patients with complex coronary anatomies and CAD demonstrated that myocardial ischaemia was more likely attributed to the disease itself rather than the unusual anatomical variation (12). However a small study involving seven patients performed quantitative myocardial perfusion imaging with PET/CTCA. They detected pathological blood flow to the territories supplied by anomalous coronary arteries suggesting their very presence is a substrate for myocardial ischaemia (13).

Cardiac Resynchronization Therapy (CRT)

Real time fusion imaging during cardiac valve operations and atrial septal closures is growing in prominence. A review of the current techniques and methods is outside the scope of this article, but it is worth highlighting the use of SPECT myocardial perfusion imaging to guide lead placement during pacemaker implantation. In 2014 a team of Chinese researchers developed a software tool to fuse fluoroscopic venograms with SPECT MPI in an attempt to help guide left ventricular (LV) epicardial lead placement (14).

In CRT, the site of the LV lead is important in obtaining the maximum resynchronization benefit. The ideal location for implantation is an area of viable myocardium with late activation. After land-marking this region with SPECT MPI prior to the procedure, a fluoroscopic venogram identified the epicardial vessel anatomy. When the two images where fused together, this enabled the operator to accurately guide the LV lead into the target region.

While this holds promise for the future, this was at best a feasibility study and more research is required to determine if there is any clinical benefit from using this technique over conventional practice.

The future of Hybrid Imaging

Future research will focus on refining available techniques, and exploring different clinical applications that could benefit from hybrid imaging. As the healthcare burden increases with an ageing population, there is a clamour for more effective rule-in/rule-out strategies before embarking on intervention with inherent risk. A growing cohort of patients with grown-up congenital heart disease presents a different challenge, but one that can potentially be mitigated by the refinement of techniques that allow co-localisation of structural and physiological cardiac abnormalities.

I feel there is scope to employ 3D Echocardiography and CTCA fusion to corroborate areas of coronary artery stenosis with abnormal myocardial strain. Already there is emerging use of CTCA and 3D speckle tracking at rest. The potential to employ a similar technique with stress echocardiography as a more sensitive method in detecting myocardial ischaemia is intriguing.

My personal view is that Hybrid imaging is a rapidly developing field with an exciting future. As the software progresses with artificial intelligence based image analysis gaining more widespread adoption, I believe availability to more clinicians will improve. Herein lies one of the current major flaws. Current accessibility is limited to researchers and tertiary imaging centres. This is driven primarily by high costs and a limited number of radiographers and imaging specialists experienced in the use and interpretation of hybrid scans. More widespread exposure is required to reverse this. Large trials proving clinical benefit above and beyond what is attainable with our current daily methods, will greatly aid in this quest.

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