Cardiac PET/MR: Big footprint—small step?

Philipp A Kaufmann, MD, FESC, FSCCT[a]

[a] Department of Nuclear Medicine, University Hospital Zurich, Zurich, Switzerland

Received Jan 30, 2015; accepted Jan 30, 2015
doi:10.1007/s12350-015-0089-4

INTRODUCTION

There is probably no technical invention which has changed more within the medical world than the discovery of the x-rays by Wilhelm Conrad Röntgen in 1895 who explicitly never filed a patent in order to facilitate the widespread availability of his invention. His discovery was indeed groundbreaking, and modern medicine is unthinkable without x-rays. Although most of the many developments in the field of imaging appear to be of modest importance compared to Röntgens invention, modern imaging seems unthinkable without the tremendous developments of the last decades. While the future of Radiology seems to be in molecular imaging based on novel tracers, the present is unimaginable without the past technical evolution which was characterized by brilliant engineers who have breathlessly shortened the time spans needed for closing technological gaps defined by an equally breathless medical community. As the footprints got bigger with the devices growing from simple gamma cameras to SPECT, PET, and finally hybrid scanners, the steps in medical imaging achieved by these advancements were of variable size. The concept of PET/CT was born in the early 1990s,[1] but only in 2001 the first commercial clinical PET/CT system was announced and shortly thereafter installed in our institution. For oncology imaging, the advent of PET/CT represented a breakthrough, causing PET alone to vanish in thin air. For cardiac imaging, the 4-slice technique available at that time in the integrated CT did not allow more than testing the feasibility of a modern concept for cardiac hybrid PET/CT imaging.[2] Before the question whether SPECT or rather PET may represent the future of nuclear myocardial perfusion imaging was ever answered, another development has entered the clinical arena—the hybrid PET/MR scanner. Comparable to PET/CT, the way from concept to realization was long and from a technical point of view, the integration of PET into an MR was a formidable challenge with three main problems which had to be solved: First, the photomultipliers used in the classic PET scanners do not work in an environment with strong magnetic fields. A strategy to overcome this was the installation of a sequential system with PET/CT or PET scanner and an MR scanner adjacent or in two separate rooms,[3] joined by a table system resulting in large installation footprints. The most advanced PET/MR devices combine the PET and MR components physically in one scanner with a single gantry[4] which required major MR hardware rearrangements to make room for the PET and development of modern PET detectors less sensitive to the MR scanner's magnetic fields. Fully integrated systems result in smaller footprints and allow for the simultaneous acquisition of PET and MR data.

Second, surface coils needed to get best MR image quality can cause unwanted attenuation interfering with the gamma rays from PET. Finally, MR data, unlike those acquired by CT, are not readily usable for attenuation correction. Different strategies to address attenuation correction have been suggested including template- or atlas-based methods, or approaches using MR image segmentation and PET emission. Thus, tremendous intellectual efforts have been done for achieving a big technical progress which has raised high hopes for substantial steps of progress in medical imaging.

Similar to PET/CT, the main applications have been suggested for non-cardiac imaging, although cardiac applications are vividly discussed. A PubMed search with the terms ''cardiac PET MR or myocardial PET MR'' revealed 274 articles on January 23, 2015. A quick look reveals that much less than 10% of these articles really deal with integrated cardiac PET/MR imaging. While numerous review articles describe the great potential and the bright future perspectives of cardiac PET/MR with an important clinical role, no studies are

Reprint requests: Philipp A Kaufmann, MD, FESC, FSCCT, Department of Nuclear Medicine, University Hospital Zurich, Ramistr. 100 (NUK D 6), 8091 Zurich, Switzerland; *pak@usz.ch*
J Nucl Cardiol 2015;22:225–6.
1071-3581/$34.00

available to substantiate this so far. The search for ideal applications has identified cardiac tumors as being among the most straightforward potential cardiac applications for combined PET/MR scanners.[5] PET is often used for staging purposes and for monitoring treatment effectiveness. As MR provides far more details with regard to tissue characterization than CT, a PET/MR scan may be superior to PET/CT when both anatomic and metabolic imagings are required. However, primary cardiac tumors are extremely rare (about 0.02% incidence in autopsies), while the most common intracavitary mass is a thrombus. Cardiac sarcoidosis is another potentially fatal disease which has been identified as a well-suited target for PET/MR imaging. In fact cardiac MR allows identification of active inflammation, focal wall thickening, wall motion abnormalities, and fibrosis. By contrast, PET suggests inflammation when FDG uptake is increased. As the disease detection by PET and MR relies on different mechanisms, the two methods may offer complementary information leading to improved diagnostic performance, whereby a really solid gold standard for proof of concept would be required.

Myocarditis may represent another domain for PET/MR imaging. It is often accompanied by hyperemia, edema, fibrosis, and impaired wall motion which can be well characterized by MR, while FDG PET may again complement the information on the inflammatory component.

But what about the most important field of classic nuclear cardiology indications, i.e., evaluation of ischemia in coronary artery disease (CAD) for which nuclear myocardial perfusion imaging is well established? Despite the technical superiority of myocardial perfusion PET over SPECT, the latter still dominates the market. An important drawback for PET has been the lack of a flow tracer for PET MPI, with a half-life long enough to allow for shipment to satellite PET centers without cyclotron and the limited availability of PET scanners. The latter may not necessarily change to the better with the introduction of hybrid PET/MR scanners. This all may sound like small steps for such big footprints. Why did we then install an integrated latest generation PET/MR in our department? Because we believe that without innovation there will be no advancements. Because we believe that without advancements there will be no progress. Because we believe that without progress there is no future. And because the saying goes that even a journey of 1000 miles begins with a single step—no matter how small the step or how big the footprint.

References

1. Townsend DW. Combined positron emission tomography-computed tomography: The historical perspective. Semin Ultrasound CT MR 2008;29:232-5.
2. Namdar M, Hany TF, Koepfli P, Siegrist PT, Burger C, Wyss CA, et al. Integrated pet/ct for the assessment of coronary artery disease: A feasibility study. J Nucl Med 2005;46:930-5.
3. Veit-Haibach P, Kuhn FP, Wiesinger F, Delso G, von Schulthess G. Pet-mr imaging using a tri-modality pet/ct-mr system with a dedicated shuttle in clinical routine. Magma 2013;26:25-35.
4. Catana C, Guimaraes AR, Rosen BR. Pet and mr imaging: The odd couple or a match made in heaven? J Nucl Med 2013;54:815-24.
5. Naeger DM, Behr SC. Pet/mr imaging: Current and future applications for cardiovascular disease. Magn Reson Imaging Clin North Am 2015;23:95-103.