Biograph mMR: System and Clinical Use Today

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Summary

This article describes the latest developments in the area of technical advancements and clinical research for the Biograph mMR. Seminal publications in the field of neurology, cardiology, and oncology will be discussed.

Introduction

The Biograph mMR (Siemens Healthcare, Germany) was introduced in 2011. So far, more than 80 systems have been sold. Early on, numerous scientific publications explored the field of technical performance and basic research. Nowadays, the majority of publications address the clinical benefits of the Biograph mMR in daily routine. An increasing number of the latest publications imply improvements in clinical practice. The clinical fields can be roughly divided into oncology (60%), neurology (25%), and cardiology (15%). These early customers have been the pioneers of guiding simultaneous whole-body MR/PET into clinical practice. While the authors have tried to cover a wide range of the available published literature, it is unfortunately inevitable that we overlooked to mention other equally important articles.

The Biograph mMR already experienced updates in hardware as well as software. Currently, the 3rd generation of the Biograph mMR is under development.

Neurology

In the field of neurological mMR, three main areas of application have been identified so far: neurodegenerative diseases, brain tumors, and methodological developments.

Fowler et al. [1] describe the particular advantages of combined MR/PET for dementia imaging using ^{18}F-Florbetapir, a β-amyloid-plaque tracer. In an approach of multiparametric diagnosis the PET information is jointly evaluated with automatic MRI-based volumetry of relevant brain regions.

A feasibility study by Jena et al. [2] indicates that PET quantitation accuracy of the Biograph mMR is similar to that of PET/CT, and is reliable in a clinical setting. Furthermore, optimal co-registration of simultaneously acquired MRI and PET data has been identified as a specific advantage in brain imaging. According to Bisdas et al. [3], the potential of MR-PET imaging for the accurate investigation of *in vivo* pathophysiology has opened new pathways for the management of gliomas. The role of combined metabolic mapping of gliomas without clear evidence of tumor grade by means of MR spectroscopy and Methionine PET was demonstrated.

Ongoing developments of brain attenuation correction methods [4–10] demonstrate promising results, which will further expand the applications in the field of neurology. The application of MR-PET currently finds increasing interest in patients with refractory epilepsy. Here, very often, only after the simultaneous MR-PET exams, the decision for a surgery can be made. Early results have been published by Ding et al. [11] and Shin et al. [12].

Cardiology

Compared to oncological applications, mMR examinations in the field of cardiology and vascular imaging are not as established in clinical routine. Most publications originate from clinical research projects.

White et al. [13] describe the benefits of simultaneous MR/PET in a case study for cardiac sarcoidosis. In the same context of cardiac sarcoidosis, Schneider et al. [14] concluded that serial assessment of edema and LGE by MRI as well as FDG-PET may be helpful for therapy monitoring and guidance of primary preventive device therapy. Inflammatory processes of

the heart and vasculature developed to a potential key application for mMR. Nensa et al. [13] identified benefits from multiparametric assessment for detection, differential diagnosis, and monitoring of acute myocarditis.

Furthermore, myocardial infarction is of growing interest for several mMR working groups. Nensa et al. [15] examined 20 patients for acute myocardial infarction. They identified potential improvements for risk stratification by assessing quantitative Information on metabolic processes. Furthermore, they project for new, specific tracers to provide valuable information of pathophysiological level.

It is to be expected that the broad clinical adoption of these cardiac indications will be accelerated in the future by the methodological advances, e.g. in cardiac MR/PET motion correction as demonstrated by Huang et al. [17].

Oncology

As expected, the oncological applications for mMR were established early on in clinical practice and research. The corresponding publications will be discussed in the following.

In a comparison study with PET/CT, Beiderwellen et al. [18] looked into 70 patients with solid tumors, including 36 liver lesions. Both PET/CT and MR/PET identified the same lesions. However, the clear advantage of MR/PET imaging was the significantly higher conspicuity of the findings due to the additional MR information and improved diagnostic certainty of the reading physician.

For prostate imaging with C11-Choline, Souvatzoglou et al. [19, 20] demonstrated the additional value of MR/PET in comparison to PET/CT for the spatial registration of lesions in the pelvis and bones. Souvatzoglou et al. foresee a diagnostic advantage for MR/PET in prostate imaging.

Further potential of mMR imaging in prostate cancer was also explored by Afshar-Oromieh et al. [21], Eiber et al. [22, 23] in particular report higher diagnostic accuracy of MR-PET in comparison to PET and multiparametric MR. These key publications concluded that prostate cancer can be detected more easily and more accurately with Ga-PSMA PET/MRI than with PET/CT and with lower radiation exposure. The specific benefit of this novel tracer has already been demonstrated by Schaefer et al. [24].

For a number of oncological diseases knowledge of bone metastases is key for thorough therapy selection. FDG PET/MRI shows high potential for the assessment of bone metastases by offering superior lesion conspicuity when compared to PET/CT, as demonstrated by Beiderwellen et al. [25] and Eiber et al. [26]. In particular, the anatomical delineation seemed to be improved by the use of a T1-weighted TSE sequence.

Catalano et al. [27] compare the influence of MR/PET and PET/CT on patient-management. The results (134 oncological patients) show that in 18% of the cases the use of PET/MR would lead to a change in therapy management.

A research field that has been gaining increasing attention is the application of mMR data in the process of radiotherapy planning. Several European groups are working on this topic. Based on their initial experience Thorwarth et al. [28] expect for integrated PET/MR to become particularly important and clinically useful for improved, individualized RT therapy planning for brain lesions.

Recently, Catalano et al. and Pirelli et al. have reported promising results in Crohn's disease using PET/MR for preoperative lesion assessment [29, 30].

It is not only the substantial dose saving of typically 30-50% by omitting the CT [31] and additional 50% due to potentially reduced tracer activity [32] that makes MR/PET interesting for pediatric* oncological imaging. Hirsch et al. [33] also demonstrated a clear advantage of MR over CT for this patient group. Specific benefits in pediatric astrocytoma patients have been described by Fraioli et al. [34]. The general potential in pediatric imaging also beyond oncology is elaborated by Purz et al. [35].

Another trend for oncological MR/PET, the segmentation of regions of different tumor biology based on multiparametric analysis is described in Schmidt et al. [36] for pulmonary lesions and Schwenzer et al. [37] for Peritoneal Carcinomatosis. Gawlitza et al. [38] use a similar analysis for the depiction of complex interactions between glucose metabolism, microcirculatory parameters and cellular density.

In the field of small lung lesions without FDG uptake, Raad et al. have published intriguing data in a follow-up setting of 207 patients using a motion-insensitive radial VIBE sequence. They could show that those lesions that would be missed if only MR-PET was applied, are most likely (97%) benign [39].

*MR scanning has not been established as safe for imagingfetuses and infants less than two years of age. The responsible physician must evaluate the benefits of the MR examination compared to those of other imaging procedures.

Discussion

After an initial phase of technical and performance evaluations within the first two years after introduction, the Biograph mMR established itself in high-end patient centered care, from diagnosis and staging to therapy planning and monitoring.

This was achieved by the groundbreaking work of all Biograph mMR users using the system in clinical research and routine operation.

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