First Experiences with the World’s First MAGNETOM Vida

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The Department of Clinical and Interventional Radiology at the University Hospital Tübingen had the rare opportunity to host the world’s very first installation of the MAGNETOM Vida, the first BioMatrix equipped scanner, incorporating the latest advances in MR technology.

Current demands for biometrical imaging and personalized medicine

One of the current trends in medicine is the acquisition and analysis of so-called ‘big data’, to improve disease management and patient outcome.

The University Hospital Tübingen has dedicated itself to this approach and founded the "Center for Personalized Medicine", incorporating all activities in this rapidly developing field. One of the central tasks is a universal database for quantitative data, so that imaging data, for example, can be correlated to histopathology, molecular biology, or clinical outcome.

The Department of Radiology is also part of this interdisciplinary center, giving us the exciting chance to perform ‘Radiomics’ on a greater scale by evaluating image phenotypes as a potential biomarker, for example, to predict and assess therapy response and outcome. However, the fundamental requirement for quantitative or at least structured data is robust and reproducible image acquisition (Fig. 1). Up-to-date Computed Tomography is the mainstay of Radiomics since it is highly standardized and accomplishable in most patients. Magnetic Resonance imaging, by contrast, provides more detailed data due to its superior soft-tissue contrast and offers complex functional quantitative methods such as DCE-MRI and diffusion-weighted imaging. However its robustness and reproducibility is often limited due to long acquisition times and the sensitiveness to respiratory and gross motion. One of the focuses of our MR research group is to develop and establish methods for clinical routine to overcome these constraints to acquire robust results in every patient. We have a long-standing experience with advanced parallel imaging methods, free-breathing examinations, compressed sensing, and novel multi-channel coils. Thus, we were very excited to be the first to work with the 3T MAGNETOM Vida1 and BioMatrix1, bringing all together work-in-progress- and prototype technology, incorporating and uniting technical and sequence advances.

Our MAGNETOM Vida

Our Magnetic Resonance Department is equipped i.a. with the 1.5T MAGNETOM Espree, Avanto®, and Aera scanners; the 3T MAGNETOM Skyra and Prisma® scanners, and the MR-PET scanner Biograph mMR. The focus of our daily clinical work is on oncological, musculoskeletal, and neuro-imaging. We have experienced a steady increase in demand particularly in multiparametric prostate MRI and functional brain MRI. We have also noticed a steady

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1 510(k) pending. The product is not commercially available. Future availability cannot be guaranteed.
increase in multi-region oncologic imaging, corresponding to the rapidly growing number of anticancer therapeutics, such as immune or antibody therapy. The latter examinations in particular are repeatedly performed in prospective studies and require a fast and highly reproducible acquisition to reliably assess therapy response.

During the first months of our early installation we performed the initial mandatory conformity marking (CE-certificate), a so-called 'MPG-(medicine devices act)-study'. This means that we had to examine a particular number of patients on both the new scanner and a routine 3T scanner (in our case MAGNETOM Skyra, Prisma®, and Biograph mMR) and compare image quality.

In short the MAGNETOM Vida features a 70 cm bore, strong 60/200 XT gradients, and a very homogeneous large field-of-view (55 x 55 x 50 cm) (Fig. 2). We believe that it combines the magnet homogeneity of a MAGNETOM Avanto and the performance of a MAGNETOM Prisma, but features the similar comfort of the wider 70 cm bore MAGNETOM Skyra. Furthermore, it features 128 receive channels enabling state-of-the-art coil technology, such as a 72-channel Spine coil, 30-channel Body coils, a 64-channel or a tiltable 20-channel Head coil. The high number of channels is particularly useful for achieving higher parallel imaging acceleration factors, significantly shortening acquisition time while maintaining adequate signal-to-noise ratio (SNR). From our experience, the combination of the 72-channel Spine coil and the 30-channel Body coil delivers up to 30% increase in SNR, particularly at high PAT-factors.

The new scanner also features a novel fully-motorized dockable table concept with an integrated respiratory sensor as well as an updated software with a user interface combining the well-known syngo MR E11-software with syngo.via functionality for viewing and postprocessing.

**First experiences with the user interface**

The new user interface and scanner software is now presented on two large 24-inch screens, one for acquisition and one for postprocessing. Thus, the technical staff can view the images and perform postprocessing, without switching the task cards, always keeping acquisition under supervision (Fig. 3).

While the new software looks quite different at first glance, the syngo MR E11-functionality is still maintained and only a few minor changes were obvious. We found that all technical staff could operate the scanner after only a short (<5 minutes) basic training. The syngo.via-interface was already familiar to our physicians, but the technical staff were also quickly able to perform basic postprocessing, such as composing and advanced postprocessing, e.g. perfusion assessment with Tissue4D was also quite quickly doable.

One of the central aspects of MAGNETOM Vida is to provide optimal reproducibility of MR studies, so that high image and data quality is guaranteed. Several Dot engines enable semi-automated acquisition of e.g. the brain, joints, or the cardiovascular system with a focus on either speed, resolution or, robustness. We were particularly interested in the new Whole-Body Dot Engine, allowing the rapid planning and acquisition of multi-region examinations, giving MRI-acquisition a feeling similar to CT, automatically adjusting the field-of-view, number of stacks, and slices (Fig. 4).
Figure 5: 38-year-old patient with hepatic adenoma. (5A) T2-weighted fast BLADE sequence: A hyperintense 2 cm sized mass in the Coinaud-segment VII. The acquisition with optimized radial spokes makes the sequence robust against respiratory motion and reduces typical star and hook artifacts. Furthermore, phase-encoding artifacts caused, for example, by pulsation, do not occur due to the radial acquisition. (5B) Diffusion-weighted sequence with b-value 800 s/mm² with SliceAdjust: The lesion shows diffusion restriction. The strong 60/200 XT gradients provide high signal even at high b-values. Slice selective shimming with SliceAdjust reduces distortion artifacts. (5C) Dixon-VIBE sequence with PAT6: The lesion shows some uptake of the hepatocyte specific contrast agent Eovist (Bayer, Berlin, Germany). High acceleration factors are possible with the combination of the 72-channel Spine coil and the 30-channel Body coil. Breath-hold duration is only 8 seconds, still delivering high image quality.

Figure 4: Whole-Body Dot Engine. The Whole-Body Dot Engine enables fast and robust multi-region imaging with reproducible results. Images show a whole-body STIR-HASTE and coronal multi-planar reconstructions (MPRs) of a diffusion-weighted and a VIBE sequence.
First experiences with the hardware

Our technical staff were very happy with the fully motorized table, making it possible to maneuver even with obese patients with ease. The respiratory sensor enables respiratory triggering even for sequences without navigator. We think that the sensor is particularly useful to monitor if a patient correctly performs the breath-hold maneuvers, so that the duration of sequences can be individually adapted to the patient’s respiratory capacity.

The two tablet-like touchscreens at the gantry were also quite popular, giving full control of the room parameters such as ventilation and volume levels. Automated coil position recognition also accelerates the workflow, as positioning of the coil center is not required anymore. The basic coil design was already known and compatible to Tim4G scanners, however many coils feature more elements such as the 72-channel Spine coil, 30-channel Body coil, or 18-channel Knee coil, while others provide more patient comfort, such as the flexible Shoulder coil or the tiltable 20-channel Head/Neck coil, allowing for more comfort in the case of cervical kyphosis.

First clinical experiences

Of course, of greatest interest to us was image quality. The multi-channel coils, particularly the combination of the above mentioned 72-channel Spine coil and a 30-channel Body coil, allow for application of high PAT-factors, such as R = 6 for CAIPIRINHA-imaging (Fig. 5).

We noticed a high diagnostic image quality even for very fast examinations such as a 5 minutes brain (T2, FLAIR, T1, Diffusion) (Fig. 6) or a 6 minutes knee examination (PD fs in 3 planes and T1). Simultaneous Multi-Slice acceleration is also available for diffusion-weighted imaging enabling acquisition of a complete body region in only 2 minutes, so that diffusion-weighted imaging of the chest-abdomen-pelvis can be performed in under 7 minutes. The whole-body-protocol can be further accelerated with a free-breathing or multi-breath-hold STIR-HASTE-sequence, which can also be acquired much faster but with similar image quality than a conventional TSE-STIR (Fig. 4). We currently aim at a 30-minute time slot for a complete whole-body-protocol, allowing for a potential dramatic increase of patient comfort and throughput.

We were also very excited to test the first commercially available version of radial GRASP1 (Golden Angle Radial Sparse Parallel MRI), enabling continuous free-breathing radial T1-acquisition with a temporal resolution of <2 seconds. The resulting images are of diagnostic quality, similar to breath-hold sequences, while the image reconstruction time (seconds per phase) was considerably faster than the first prototypes, due to the two integrated GPUs.

Figure 6: 72-year-old patient with Glioma examined with a 5-minute protocol. Images were acquired with the tiltable 20-channel Head/Neck coil and integrated CoilShim. An ultrafast protocol was acquired with (6A) T2-weighted HASTE, (6B) Quiet FLAIR, (5C) DWI with b-values 0 and 1000 s/mm² and (6D) two FLASH 2D-sequences showing edema and contrast uptake of the right frontal lobe. The patient’s comfort was improved thanks to the short acquisition time, while diagnostic image quality is maintained.
Figure 7: 27-year-old patient with Hughes-Stovin-Syndrom and M. Behçet with a ventricular thrombus. (7A) Single slice short-axis cine sequence acquired during one breath-hold (8 s) at a 3T MAGNETOM Prisma®. (7B) Whole-heart cine sequences accelerated with compressed sensing acquired during one breath-hold (18 s) at the 3T MAGNETOM Vida.

Figure 8: 57-year-old patient with parotid cancer. Diffusion-weighted images (b-value 800 s/mm²) acquired with the tiltable 20-channel Head/Neck coil. (8A) The standard shim shows heavy distortions and almost no anatomical structures. (8B) SliceAdjust decreases distortions, however image quality is still impaired. (8C) The combination of SliceAdjust and an integrated CoilShim provide good image quality without distortion even of the lower neck, allowing optimal delineation of the cervical lymph nodes.
Other applications profiting from compressed sensing include, for example, cardiovascular examinations. We were able to obtain a complete short axis scan of the whole heart during only a single breath-hold, using Compressed Sensing Cardiac Cine. The diagnostic image quality is similar to that of classic single-slice acquisition requiring multiple breath-holds, so that examinations are significantly shortened, improving patient comfort and workflow (Fig. 7).

The strong gradients and homogenous magnetic field also allow for examination of obese patients, advanced diffusion applications, such as high b-value imaging and high-resolution 3D-imaging. Furthermore slice selective and dedicated coil-shims allow to decrease distortion artifacts e.g. of diffusion-weighted imaging, particularly at problematic body areas, such as the neck (Fig. 8).

Altogether we experienced an image quality, very similar to that of a MAGNETOM Prisma, which however comes with a 60 cm bore. The multi-channel coils may allow further acceleration, making it possible to shorten examination time, so that robust imaging data can be derived from every patient.

**Where do we see the MAGNETOM Vida**

As the MAGNETOM Vida brings together many advanced hardware and software solutions, we plan to use the scanner for clinical applications related to biometrical disease assessment. In the framework of our ‘Center for Personalized Medicine’ we will perform multiparametric assessment of primary tumors such as ENT-tumors, sarcoma, glioma, or prostate cancer to gain further insight into tumor biology and predict outcome and therapy response. Highly standardized multi-region examinations to objectify therapy effects will also be performed at this scanner. We also seek to quantify these effects and study tissue and tumor microcirculation and -structure with GRASP and advanced diffusion-weighted imaging. The rapid and free-breathing imaging possibilities allow us to quickly examine children\(^2\) or patients with limited general condition or respiratory status and to obtain adequate image quality in the shortest possible acquisition time.

In summary, the MAGNETOM Vida will enable us to acquire robust and reproducible imaging data in almost all patients, forming the groundwork for biometric MR-imaging, personalized medicine and individually tailored therapies.

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\(^2\) MR scanning has not been established as safe for imaging fetuses 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.

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**Embrace human nature**

**with**

**BioMatrix Technology**

Patients have unique, individual characteristics. Different physiologies and anatomies – but also the way we interact with them and technology – cause unwanted variability. These unique human characteristics, or biovariabilities, present a challenge and a source of error, rescans, and inefficiency when it comes to MR imaging.

This intrinsic patient variability needs to be addressed in order to truly personalize MRI, and pave the way towards precision medicine. To turn this challenge into an opportunity, we must think differently. Instead of adapting human variability to technology, we adapt technology to humans. We do this by embracing their individual nature – with BioMatrix Technology.

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