The potential of low-field MRI

an initial experience with a small, wide-bore 0.55 T MRI in a real life clinical setting

Founded more than 700 years ago, the Basel University Hospital is one of the oldest hospitals in Switzerland. Despite its venerable age, the hospital has a deserved reputation for using the most up-to-date technology whenever clinically appropriate. An example of this is the recent acquisition of a small, 0.55 Tesla, wide-bore MRI scanner, the Magnetom Free.Max from Siemens Healthineers. We wanted to find out more about the clinical experience with the new system so far and the potential of low-field MRI in general, so we spoke to Prof. Elmar Merkle, head of the Department of Radiology, together with Dr. Hanns-Christian Breit and Dr. Michael Bach.

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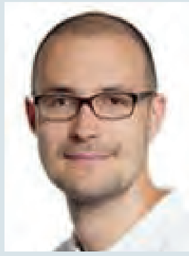

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Q *Before we get into discussing the new MRI system, please give us a brief background to your hospital itself and the central radiology department.*

In 2020 we performed a total of 145,315 imaging examinations of which 49,188 were CTs and 22,021 MRIs, Focussing on MRI, the principal indications were joints, prostate and brain imaging. To carry out this workload we have three 3T scanners (2 Siemens Healthineers Magnetom Skyra, & 1 Siemens Healthineers Magnetom Prisma) and two 1.5T systems (Siemens Healthineers Magnetom Avanto). The latest arrival and completing our current range of MRIs is the new Siemens Healthineers Magnetom Free.Max 0.55T whose installation here in Basel was one of the first in the world.

Q *So let's turn to the Magnetom Free.Max.*

The system was actually installed in March of this year, with the first patients being scanned at the beginning of May after the system received the CE mark.

As for the installation itself, that was greatly facilitated by the small dimensions and weight of the new 0.55 T system. For the first time with an MRI installation, we were able to physically deliver the machine simply through the standard hospital corridors. The contrast with the installation of our higher field systems was stark — for the 1.5T and 3.0T systems we were obliged to break down the external wall of our building, resulting in substantially higher costs of time and money. In addition the 0.55T machine uses only a small amount of helium, so there is no need for expensive helium quench evacuation piping. Overall, we calculated that the costs of preparing the site before installation were 30% lower for the Magnetom Free Max than for "conventional" MRI scanners.

Although the scanner has significantly smaller dimensions than the higher field models, we deliberately installed it in a generously spacy room, since we anticipate that ICU patients, with all the associated ancillary equipment, will also be imaged in the future. In terms of actual patient handling and operation, the low-field system behaves just like our higher field machines so we don't need a dedicated team of operators specialized on one system — our operators can be freely assigned to machines of any field strength.

The learning curve for the radiographers was straightforward — comparable to that after a major software update or installing a new "conventional" MRI and was made easier by our familiarity with other Siemens Healthineers MRI systems.

However, given that this is a new scanner with a "new" field strength, we had quite a lot of work to do on the initial set-up of the sequences, with a radiologist and a medical physicist devoting nearly a month full-time to set up the most important protocols. Other hospitals may not need to start from scratch like this, — perhaps that's the downside of being the one of the first installations in the world — but it is unavoidable that sequence optimization is a time-consuming process, albeit a necessary one for validation and to fulfil the maximum potential of the machine.

Q *How many patients have you seen so far in the new system and what are your first reactions?*

We have seen approximately 150 patients so far, including some volunteers scanned for test purposes. So far with the new system we have been focussing on patients with metal implants, as well as spine imaging, (experimental) lung imaging and for patients from the emergency department. For spine, stroke, hip, abdominal and joint imaging we use the same pulse sequences as on our other scanners (T1/T2/PD, TSE, EPI, SWI, TOF, HASTE, TRUFI, VIBE, DIXON, SPACE).

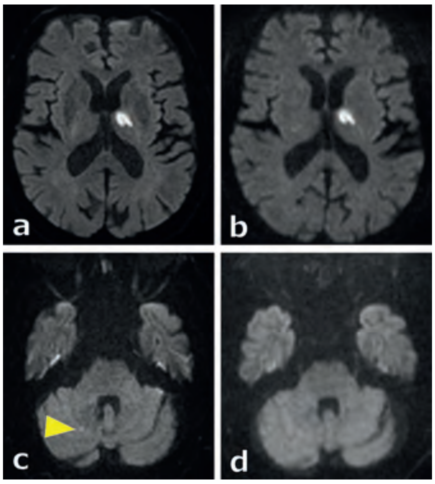

Figure 1. Stroke patient. DWI, b = 1000 s/mm^2, slice-thickness = 3 mm.
Top Panels. Image (a) acquired by Magnetom Avanto 1.5T, Time of acquisition (TA): 2:06 min compared with (b) Magnetom Free.Max, 055T, TA 4:35 min. The stroke area is clearly depicted on both systems. Bottom Panels. Image (c) acquired by Avanto I.5T compared with image (d) acquired by Free.Max. Small stroke lesion (less than 2 mm, yellow arrowhead) is missed occasionally at lower field strength. We are currently investigating these findings in more depth.

We'll talk about image quality, noise and performance later on, but one first, non-radiological impression was how useful and appreciated was the wide bore, especially when we're dealing with obese patients — the Free.Max has a bore diameter of 80 cm. Since acoustic noise varies with field strength, we expected our patients to positively comment on the low noise levels in the new system, but in fact the patients' messages about noise weren't clear-cut — some even thought the noise level was higher than with our 1.5T systems. We haven't yet carried out objective acoustic noise measurements.

Q *What about image quality and general system performance?*

Given that our experience so far has been with 1.5 and 3.0T systems, we had some initial scepticism about image quality at 0.55T, but we are confident that the new system can nicely complement our existing MRI scanner spectrum. As for spatial resolution, there are some cases, such as knee and brain, with their need for higher resolution, which are challenging and could even be borderline. However these cases can be handled using our existing policy of triaging specific examinations to appropriate scanners.

In general, the Signal to Noise ratio (SNR) is proportional to the magnetic field so, at a first cut this means that the signal at 0.55 T is roughly only 40 % of that at 1.5 T. However the use of lower field strength actually also has three characteristics that can have a significant favourable effect on SNR. First, a lower bandwidth can be used to achieve the same chemical shift. Secondly, the Specific Absorption Rate (SAR) is reduced by a factor of 7.5 / 30 in comparison to 1.5T / 3T scanners respectively so it is usually not necessary to use refocusing flip angles below 180°, which improves SNR. Finally, T1 is shorter at 0.55 T, which also helps to increase SNR. Taking all these effects into account together we are roughly in the range of 60 to 70 % SNR compared to a 1.5 T system.

In practice we can accept a lower SNR — as long of course as the image remains of diagnostic quality. We could improve image quality by going for a longer acquisiton time, depending on the indication, the sequence and the imaging region. However we use the AI-derived algorithms and simultaneous multi-slice imaging to keep the measurement time as short as possible. Currently, we are investigating the Deep Resolve postprocessing in detail and use it in most of our protocols. There are several parameters, for example the sequence type, body region, or original resolution that can influence the final result but we need to investigate this in more detail.

The Deep Resolve reconstruction process takes a bit more time, but even then there is only a small delay (less than one minute) compared to standard reconstructions.

Our first impressions of susceptibility related artifacts are that they are significantly reduced. Certainly, the imaging of metal implants seems to be very promising.. Finally, one other area where we were pleasantly surprised was in fat saturation, since generally, the lower the field strength, the more difficult is spectral fat saturation, as the frequencies of water and fat come closer. In fact we observed that spectral fat saturation worked better than expected.

Q *How do you assign patients to either the 0.55 T MRI or to higher field MRI?*

We always assign patients depending on the indication, For imaging of joints and brain, e.g. brain nerve protocols where higher resolution is required, we would prefer to go for scans at higher field strength, whereas in general we would prioritize scanning at 0.55T for patients with particular patient-related circumstances such as obesity or claustrophobia.

Q *So what is your impression so far of the Siemens Healthineers Magnetom Free.Max?*

Overall, it is a robust tool which completes our scanner-portfolio and is especially suitable for imaging of patients with metal implants. There are still some limitations as concerns resolution in joint imaging and in several other specialized imaging protocols, e.g. prostate imaging.

Of course as radiologists we are always looking forward for further improvements,

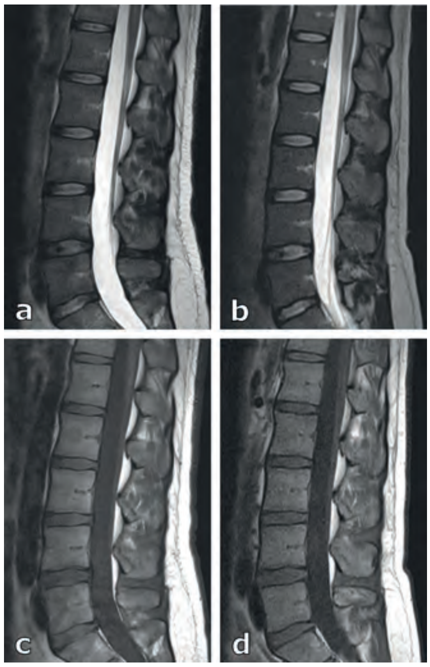

Figure 2. Standard spine examination. Magnetom Avanto 1.5T images (a) and (c) and Magnetom Free.Max 0.55T images (b) and (d).

Comparison of (a) vs. (b). Sagittal T2 TSE, slice-thickness: 4mm. (a) Avanto 1.5T, TA: 1:44 min. (b) Free.Max 0.55T, TA: 3:36 min.

Comparison of (c) vs (d) Sagittal T1 TSE, slice-thickness: 4 mm. (c) Avanto 1.5T, TA: 2:29 min. (d) Free.Max 0.55T TA: 2:28 min.

The image quality at the lower field strength is comparable to that of 1.5T and certainly of diagnostic quality.

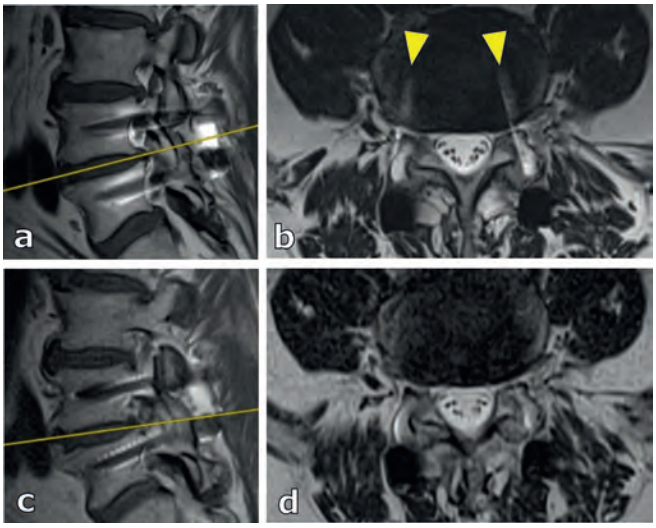

Figure 3. Spine implant examination, comparison between the Avanto 1.5T (top) and Free.Max 0.55T (bottom).
Artifacts are less pronounced on the Free.Max system
Metal artifacts in the oblique transversal plane (between the pedicle screws - yellow lines in (a) and (c)) are seen at 1.5T (b, yellow arrowheads) but not at lower field strength (d). Acquisition times for images (a),(b),(c),(d) are: 4:19 min, 3:37 min, 3:54 min, 4:07 min respectively

so on our personal wish-list we would like to see coil development, more powerful AI-solutions to improve SNR and resolution and acceleration techniques. Another positive development would be more powerful gradients.

Q *Do you think that the small foot-print and easy installation of the Magnetom Free.Max could open up the use of MRI in places where MRI is not usually available, e.g. the ICU ?*

Yes. A low-field MRI inside the ICU would provide rapid access to advanced imaging for patients who have a high demand for highly specialized medicine — including imaging — without the need for cumbersome transfer of the patient to a central radiology facility. There are indeed quite a number of indications e.g. stroke patients or infection cases, which may require further imaging but which cannot be adequately handled by the only imaging modality usually available in the ICU, namely ultrasound. Another advantage of the Magnetom Free.Max in such a context its low level of susceptibility artifacts, that can be caused by intracorporeal catheters and devices which are often placed in ICU patients. Of course if an ICU patient needs MRI, then it will be carried out if at all possible. Currently this means transfer of the patient to the radiology department; for these very sick patients this can be quite complicated logistically and uses up precious time of busy ICU personnel.

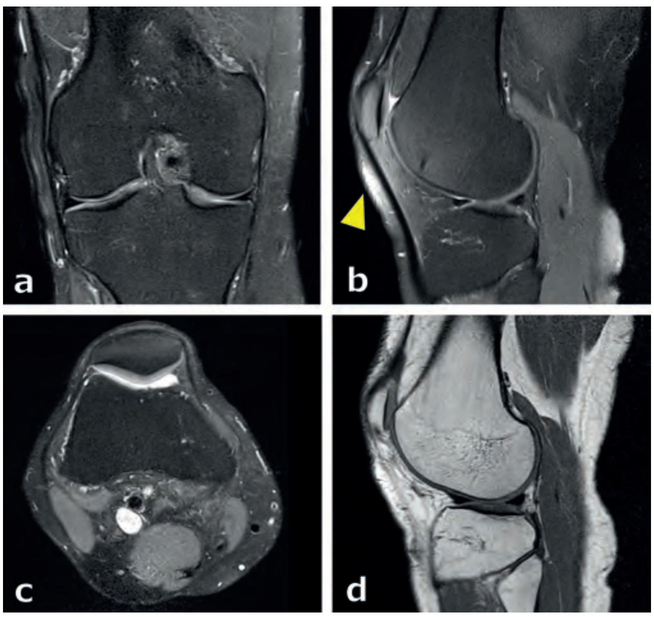

Figure 4. Standard knee examination at the Magnetom Free.Max.
(a) Coronal PD TSE with fat saturation, Acquisition time: 2:58 min.
(b) Sagittal PD TSE with fat saturation. Acquisition time: 3:43 min, Minor fat saturation problems occur in the area anterior to the Hoffa fat pad (yellow arrowhead).
(c) Transversal PD TSE with fat saturation. Acquisition time: 2:47 min.
(d) Sagittal T1 TSE. Acquisition time: 1:51 min.

Ideally, we could envisage such an MRI imaging service in the ICU being operated 24/7 by ICU personal as well as by radiology staff. In any case the diagnostic evaluation would always be provided by highly specialized radiologists, so hopefully the service could be run successfully without any "turf wars" breaking out.

We have been talking so far only about a possible use of the low field MRI in the ICU, but since we are in a speculative mood, we could also envisage the use of a small footprint MRI system in other locations, such as the emergency department, where it would provide immediate access to imaging of acceptable diagnostic quality.

Q *Continuing the "blue sky thinking" could the new MRI play a role in post-COVID hospital environments where there is likely to be more emphasis on reducing the need for inter-department transfers of patients?*

As in most hospitals we found here in Basel that during the COVID-19 pandemic the provision of vital imaging services to patients with COVID was really challenging logistically, so anything that could reduce the need for the inter-departmental traffic of transfer patients who are highly infectious and/or in critical condition would of course be welcome.

But more broadly what we're talking about here is the issue of access to MRI in general. In Switzerland we have one of the highest number of MRIs per million of population, with 215 scanners in the hospital sector alone (the population of Switzerland is approximately 8.5 million). Thus, waiting times for MRI in Switzerland are low, typically about one week, although that of course depends on the indication and examination. If necessary we at Basel provide immediate imaging for any patient 24/7. However the level of access to MRI that we have in Switzerland isn't the same as in other countries. Developing countries in particular could benefit from the lower costs and installation requirements, which are major advantages of the new low-field system. In this way, we think there is a great potential to improve diagnostic possibilities via MR imaging in many areas of the world.

Q *Do you think that the era of domination in MRI by 1.5T/3.0 T systems is now definitively over or will they still remain a vital component in MRI for the foreseeable future?*

We think 1.5T and 3T systems will still remain the mainstay of MRI imaging but they could be usefully complemented by new low-field scanners which can provide imaging of diagnostic quality in several particular examinations. We can even imagine specific areas where low-field MRIs could be better, e.g. the metal artifacts shown above.

Finally, given the incessant increase in the demand for MR imaging, the significant economic advantages of low-field MRI can't be ignored.