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COMMENTARY

ESMRMB annual meeting roundtable discussion: "when less is more: the view of MRI vendors on low-field MRI"

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Introduction

As part of the program of the upcoming 2021 Annual meeting of the European Society for magnetic Resonance in Medicine and Biology (ESMRMB), the Congress Planning Committee challenged various vendors involved in the low-field MRI market to join a Roundtable Discussion.

Low-field MRI has emerged as not only a mean to address the access inequality to MRI both worldwide and within developed countries thanks to its reduced costs, but also as a mean to overcome some of the artifacts present in high field systems. With these motivations in mind, low-field MRI has become increasingly popular as testified by the recent appearance of various new commercial low-field MRI systems and parties, but also by the amount of research work published. This has been particularly visible in the emergence of scientific, educational and plenary sessions on this topic at the annual meetings of the International Society for Magnetic Resonance in Medicine as well as the appearance of various reviews covering the topic [1–5]. The spectrum of low-field systems and applications is particularly large. There are currently commercial systems ranging from 0.05 to 0.6 T, with magnet technologies ranging from permanent to electromagnet and superconducting solenoids that are virtually helium-free MR systems. Systems designs vary from open to compact, portable to fixed depending on the applications envisioned.

For this Roundtable Discussion, we have made an effort to include representatives from vendors that represent a large range of views into the Low-Field MRI market, not only of the MRI setup and applications, but also of the background of the representatives:

- Stefano Gazzo, Sales and Clinical Specialist of ASG Superconductors/Paramed MRI unit—Open-sky MR system used for multi-position, weight bearing imaging and MR-guided radiotherapy 0.5 T;
- Wim van Kemenade, MRI Communication manager from Esaote—Open system with weight bearing flexibility (0.25 T) and compact systems for extremity imaging 0.31 T;
- Jeff Stainsby, MRI Scientist of Synaptive Medical—Compact 0.5 T system with high performing gradients for neuroimaging;
- David Grodzki, MRI Scientist for applications of Siemens Healthineers—"Traditional" whole body MR scanner at 0.55 T;
- Edmond Knopp, Senior Medical Director of Hyperfine—Portable MR system point of care system at 0.065 T.

In preparation for the roundtable discussion, we have invited representatives to present a short pitch on three questions, which we share with the community in the following sections.

1. What are the main new technologies (to be) present on their systems that would not have been possible 10 years ago and contributed to their product over the last 5 years?
2. Where will the low-field MR market grow in the coming years?

Wim van Kemenade, Stefano Gazzo, David Grodzki, Edmond A. Knopp and Jeff Stainsby contributed equally to this commentary.

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3. What are the strengths, weaknesses, opportunities and threats (SWOTs) of low-field MRI.

1. What are the new technologies that have transformed (your) low-field systems in recent years?

According to Esaote, "…the shift from hardware-based improvements to software based solutions for scan-time reduction and image quality improvements has given a substantial boost particular to low-field MRI. Small but powerful computers in combination with of-the-shelf highly efficient image elaboration hardware e.g. from the gaming industry allows for easy implementation of sophisticated acquisition and reconstruction algorithms without altering costs. A typical example is the compressed sensing algorithm, applicable to almost all sequences with the ability to reduce scan times by as much as 40% without altering hardware components. These advances have substantially decreased the gap between high- and low-field MRI in terms of quality and throughput."

For Paramed MRI Unit/ASG superconductors "magnet strength is the main driver of SNR in MRI and pushing to higher field has been for decades the main source of improvements. One disruptive new idea in a different direction has been the application of Compressed Sensing algorithms to MRI introducing the capability of substantially undersampling K space without significant image quality reduction. Low cost computational powerful device (GPU) brought that technique in the range of economic feasibility even for less costly devices.

Parallel to that, the cryogen-free technology for superconductive magnet like MgB2 wire from ASG Superconductors, further improve the freedom to design open structure capable of new clinical applications."

From the point of view of Siemens Healthineers, "… compared to one decade ago, several aspects have changed. Computing power became much cheaper and easier accessible, allowing for a broader use of digitalization technologies. These include new acquisition technologies (e.g. SMS, Compressed Sensing) as well as deep-learning-based approaches that, for example, may help to de-noise images, increase effective resolution, or speed up the acquisition. In addition, also on the magnet and RF-receive side, substantial improvements have been achieved, allowing for larger bore sizes, low-helium magnets and improved SNR recovery. The combination of all those points made lower field strengths in MRI appealing again."

For Synaptive Medical goal of "high-quality imaging at 0.5 T required the application of both new technology and existing advanced technologies not commonly applied to 0.5 T. Advances in cryogen-free magnet design eliminates the need for a quench pipe which improves siting constraints and enables the ability to turn the magnet on and off in as little as 10 min. System components with specifications equal to, or better than, what is typically available on high-end, high-field systems including extremely high-performance gradients (100 mT/m, 400 T/m/s), a powerful transmit system (60 uT), a fully digital receive chain and advanced pulse sequences, can all be leveraged to optimize imaging at 0.5 T and overcome the perception that low field equals low-image quality."

In addition to many of the previous points, for Hyperfine to create the first portable scanner (on wheels) to be used "in various environments (ICU's etc.) the system employed technology analogous to noise cancellation headphones to eliminate the EM and RF interference in the local scanning environment (Ventilators, Physiologic monitors, ECMO pumps etc.). Furthermore, the system is designed to allow it to be driven and moved thru any clinical environment (battery operated drive mechanism, with a size and weight to allow entry through standard doorways and passenger elevators)."

Summary

It is interesting to note that the advances that have made these products competitive today, as highlighted by the representatives, include improvements in magnet (Synaptive, Paramed, Siemens Healthineers) and gradient (Synaptive), RF receiver chain (Siemens Healthineers, Synaptive and Hyperfine), computing power (Esaote, Paramed) hardware technology, combined with the rise of modern acquisition and reconstruction approaches (transversal to all vendors). Thus, these improvements are present in the entire hardware and software chain of the MR image creation.

2. Where do you see the low-field MR market grow in the coming years?

For Hyperfine, "the advent of portability, allows for the possibility of brain imaging (FDA cleared) at the bedside with critically ill patients or infectious critically ill patients (Covid-19). As this technology continues to be adopted, use cases such as: ICU imaging, follow-up ICU imaging, changing the stroke workflow and hydrocephalus (most notably pediatric) are all envisaged growth segments. The system enables MR imaging in locations to answer specific clinical questions as a means to effect more targeted and appropriate patient care."

Esaote has identified "several growth potentials for low-field MRI systems. As a 2nd or 3rd system in the hospital, as a department MRI imager in a hospital and as primary system for specialized and smaller clinics with a reduced patient load. Remote places where spare part delivery can be an issue, where there is unstable electric network or no

access to Helium (all issues that are still the case in a relative big part of the world) will benefit from the ow field system robustness."

Paramed MRI expects that "all the new technologies merged with some specific capabilities offered by these scanners like design, magnet technology and dedicated focus on specific anatomies or specialties, are creating different niches to unload the 1.5 and 3.0 T scanners from the normal clinical routine offering a solid option for clinicians and, finally, for patients. In addition, there are some procedures available only with these scanners. Differentiation should be a key-word in the future MR market to enlarge the patient population and to have an accurate specialty-driven clinical output."

For Siemens Healthineers, "the main benefit of low-field systems are the lower purchasing costs as well as the reduced infrastructure requirements. Therefore, the markets of low-field systems are on the one hand emerging markets with strong cost pressure and challenging infrastructure conditions, e.g. with regards to helium supply. On the other hand, such solutions provide new opportunities also in developed markets, like in de-centralized community settings or special departments. Those can be ICU or emergency rooms."

Synaptive sees as the strength of low-field MRI in "imaging patients who find access to MRI challenging. Low field has inherent advantages in having reduced distortion and artifact in areas of high susceptibility (for example arising from air-tissue interfaces at the skull base or near the sinuses) and thus can provide imaging details not possible at higher field. Lower field is associated with significant reductions in patient and device heating, paving the way to scan patients who were not previously good candidates for MR imaging. The lighter, smaller footprint systems can more easily installed closer to the patients who need MRI, for example in the ER, ICU or OR."

Summary

The foreseen growing markets are particularly broad as the various vendors have different markets in sight: from ICU to Emerging economies; from specialized MRI to the MR system with large subject compatibility.

3. SWOT analysis

We next challenged the participants to create a SWOT table. The combined table is outlined below with items ordered by frequency of response across manufacturers.

Strengths:

- Siting considerations
- Low cost
- Design flexibility
- Reduced subject safety concerns
- Reduced image distortion
- Interventional MRI
- Patient comfort
- Portability

Weaknesses.

- Low SNR
- Scan duration
- Reduced range of contrasts (for example: low/no susceptibility contrast or angiography in some setups)
- Lack of literature on advanced methods at/for low field
- Lack of training for radiologists to read low field

Opportunities.

- Dedicated systems for specific departments
- Running and owning costs
- New settings (ICU, ECR, Ambulance, Clinics)
- Value based medicine
- Emerging markets
- Applications such as: MSK, imaging close to implants, surgical planning and interventional

Threats.

- Radiologists perception of low field = low quality
- High field innovations that mitigate low field advantages
- Cost reduction of 1.5 T (advent of helium free designs)
- Challenges of siting radiological devices outside radiological departments
- Insurance, Certification and Regulation
- Increase of price of rare earth metals

Conclusion

We hope this commentary article sets up the floor for an enriching discussion in the 2021 annual meeting of the ESMRMB on the opportunities for the various flavors of low-field MRI. Furthemore, we hope this round table discussion contributes to our researchers and MDs to get a clearer view of what can be achieved with todays with low field MRI and what were the paradigm shifts that have contributed to its reemergence.

Declarations

Conflict of interests Mr Wim van Kemenade is an employee of Esaote SpA, Mr Stefano Gazzo is an employee of ASG superconductors SpA, Dr. David Grodzki is an employee of Siemens Healthineers, and Mr

Edmond A. Knopp is an employee of Hyperfine Research Inc and Dr. Jeff Stainsby is an employee of Synaptive Medical.

Ethical Standard This article does not contain any studies with human participants or animals performed by any of the Authors.

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