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Cardiovascular 7T MRI moves from dream to reality

Cardiovascular MR (CMR) has evolved rapidly over the past decade, with the results feeding into a broad spectrum of clinical and research applications. The development of faster CMR techniques and advanced MR hardware is largely driven by the need to overcome physiological constraints inherent in clinical cardiovascular imaging, such as motion and blood flow.

One important development in MR research is the move toward whole-body ultrahigh-field systems. This trend began with pioneering explorations into neurovascular MRI at 7T. Now cutting-edge MR centers in Europe are investing in 7T MRI to explore regions outside the brain. These efforts hold great potential for basic cardiac research and clinical applications, with the ultimate goal being the advancement of cardiovascular imaging.

Increasing field strength in MRI leads to gains in signal-to-noise ratio, the "currency" of image quality, as well as to faster imaging speeds that can enable efficiency gains. These advances are being driven by the clinical need to streamline structural and functional cardiac imaging. Another motivation for increasing CMR sensitivity, and hence moving to ultrahigh-field imaging, is the desire to facilitate targeted tissue characterization and noninvasive biopsy through molecular imaging and parametric mapping. Such techniques could make it easier to visualize (patho)physiologic processes and mechanisms, increasing the range of CMR indications in a variety of cardiovascular disorders.

Unfortunately, the potential of many ultrahigh-field CMR applications is as yet untapped, and they are sometimes described as "blue sky investigations." Even early adopters of high-field systems regard ultrahigh-field CMR as one of the greatest challenges facing clinical MRI. Clinical users of 3T MRI already know that high-field CMR imaging presents a number of specific challenges. These include interference between ECG signals and electromagnetic fields, magnetic field inhomogeneities, radiofrequency nonuniformities, and RF power deposition constraints. Some of the inherent advantages of ultrahigh-field MRI may simply be counterbalanced by practical and technical obstacles.

The pace of discovery and progress, however, is encouraging. Cardiac MRI studies have been performed at 7T using multitransmit MR systems, local transmit/receive coil arrays, and novel acoustic triggering techniques. The resulting image quality offers detailed insights into cardiac anatomy and allows accurate delineation of myocardial borders, a feature that is essential for cardiac chamber quantification.

As ultrahigh-field CMR applications come closer to routine clinical practice, economic considerations will have to be taken into account. The ratio of cost to clinical benefit currently comes out in favor of lower field systems, not 7T. But there is light at the end of the tunnel. Appropriate hardware design, including the advent of actively shielded 7T whole-body magnets, should help offset economic constraints. An optimistic practitioner might envision a clinical role for 7T CMR in the future, though this is, for the moment, merely a vision. It is nonetheless a vision that continues to inspire basic and clinical research into ultrahigh-field CMR. The field may still be evolving, but it is also maturing.

Demonstrable progress in ultrahigh-field CMR is providing encouragement for the imaging community to solve any outstanding issues. Achieving this goal will require a strategic, interdisciplinary research effort driven by scientists, clinicians, and innovators. Their efforts should be devoted to improving ultrahigh-field MRI technology so that new ways of mapping cardiac morphology, function, physiology, and metabolism can be realized. Previous limits on resolution, speed, and contrast are not fundamental, as this work will show. Practitioners may be inspired to move from organ-level imaging to the tissue, the cellular, and maybe even the subcellular levels, connecting basic cardiac research to clinical applications and vice versa. The benefits and challenges of ultrahigh-field imaging in cardiovascular and molecular MRI applications should also be explored.

Today's advanced ultrahigh-field CMR techniques remain intriguing and are in a creative state of flux. They nonetheless promise to bring the field of diagnostic cardiovascular imaging closer to the heart of the matter.

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