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The Nexus of MR with Artificial Intelligence

Dear readers and colleagues,

Artificial intelligence (AI) is maturing at a time when the need for health care transformation is enormous. We are faced with spectacular challenges in medicine and specifically in radiology by virtue of our penetrance to every patient and our impact on diagnosis, patient disposition, intervention, and costs. This nexus is manifest through AI enhancements along key vectors of innovation acquisition, diagnostics, and operations that are evident throughout this volume.

There is a natural tendency to gravitate to technological solutions to complex problems, particularly in medicine. As a medical student contemporary to the advent of magnetic resonance, the cell phone, and searchable library databases, my pocket brain was analog. Now technology brings knowledge immediately to our fingertips. Magnetic resonance sparked my interest in radiology at that time, and the amazing potential of MR continues to grow and intrigue. We are faced with expanding challenges to human cognition and complex information processing demands that exceed the capabilities of the most apt pupils. The convergence of need and technological advances engenders optimism, but it will require rethinking how we work.

AI in radiology can improve precision medicine, productivity and patient care through simplification of workflow, more efficient use of physician time, improved patient experience, and integration into the digitalized future of healthcare. AI is expanding our views of what is possible in the promotion of health, detection of disease, and optimization of treatment. The expanding interconnectedness and velocity of information flow within and between disciplines is exceeding existing routes of communication. Massive, transformative changes in infrastructure and our expectations will streamline patient care delivery in a future is being built today. Siemens Healthineers' academic-industry partnerships leverage mutual and complementary strengths in care delivery, critical thinking, rapid innovation cycles, and pragmatic deployment of new discoveries. We are proud to be part of the Siemens Healthineers strategic network helping to define and iterate the path to the future.

Much of the AI development is being driven by the demands of increasing specialization, more sophisticated algorithms, and massive data streams that need to be effectively managed in order to distill the best course of action. Humans need help. The community of like-minded collaborative scientists in the public and private sectors are engineering solutions for the health challenges facing our populations. It is in this context that I anticipate this edition of the MAGNETOM Flash. Innovation in the Siemens MR community is inspiring creative contributions to all aspects of value chain that MR provides. Computer-aided diagnosis foreshadows the promise that is AI but is only one of the many attractive facets.

After training at Duke University Radiology and Johns Hopkins Neuroradiology he returned to MSU, his alma mater to direct the MR section at MSU in East Lansing. Dr. DeLano was privileged to participate in the early development and adoption of 3T MRI in clinical practice, running a full-time, comprehensive whole body MR scanner schedule beginning in 2001. He has presented nationally and internationally on his diversified research and translational clinical experience across multiple subspecialties including cardiovascular and musculoskeletal radiology in addition to his primary specialty of neuroradiology.

His mentorship and teaching in the medical school and the MSU/Spectrum Health Diagnostic Radiology Residency spans neuroradiology, MR techniques, and cardiovascular thoracic imaging. At Spectrum Health Dr. DeLano leads cross-disciplinary initiatives in care pathway development and implementation. He facilitates AI adoption, informatics integration, and lean management in radiology throughout the system.

Patient centric MR and precision health

Technology maturation is actuating the 20+-year-old Zerhouni championed vision of precision healthcare espoused in his roadmap for clinical and translational research [2]. He described the development predictive, personalized, preemptive, and participatory future of medicine. Our ability to achieve this future state is enhanced by on our assimilation of technology into our standard work as we interpret imaging in consultation with our clinical colleagues and increasingly in partnership with our digital colleagues. AI is the piece that helps these concepts become seamlessly integrated into our common experience. Imaging of the future will capitalize on the detection of genotypic and phenotypic features and will stratify patients in terms of risk including prognosis and survival likelihood. The expansion of precision medicine toward this "4 P model" results from the confluence of technological innovation, economic imperative, and ethical necessity. This vision for the future is becoming our present reality. AI and advanced technologies are shaping how MR is conducted provides a window on a very bright future.

What is most compelling at this juncture is the increasing integration of AI technology into our workflow and the delivery of individualized health care. Technology is becoming quietly smart. Rather than a disruption, it is an integral partner in our quest to advance the care of our sick and maintenance of health. Technology is being designed to anticipate our needs and improve our performance, informed by data and personalized to the user and the patient.

Patient adaptive BioMatrix Technology

BioMatrix Technology is designed to advance toward the seamless integration goal, and the care of patients is being enhanced by these creative innovations and novel applications. These literally and figuratively touch the patient at all points of care, from patient preparation, image planning and acquisition, image reconstruction and distribution, image postprocessing and interpretation. Patients have unique, individual characteristics or biovariabilities that cause unwarranted variations in imaging results. BioMatrix helps to overcome these challenges by automatically adjusting to individual patients. By "embracing human nature" in this way, examinations are personalized and help expand precision medicine. AI powered BioMatrix and GO Technologies increase throughput, and integration into workflow is fundamental to the facilitating high quality and high-volume work while keeping patient comfort in mind.

MR driving quality and the triple aim

Avedis Donabedian's seminal work on the quality provision of health care set out necessity of attention to the structure, process, and outcome [3]. The structures and processes are evolving and the outcomes are increasingly important to drive the innovation feedback loop as we strive toward the triple aim. The structures we rely on continue to improve. This is evident in the adaptation of clinical imaging to increasing field strength, higher performance of the radio frequency architecture and gradients,

and more efficient coils. The processes that benefit the drive to value include BioMatrix empowered adaptive sensors that tailor exams to the individual's anatomy and physiology. AI and deep learning enhanced reconstruction algorithms also are value added process steps.

Ultimately, better outcomes are dependent on the integration of multiple advancements that reduce the work of the healthcare team and improve the experience of patients.

The health care system, doctors, and patients have the parallel needs. Paraphrasing Engelbert and Hagel, we need to foster environments where people engage in more fulfilling and inventive work that allows them to realize their full potential, augmented by technology to perform routine, often tedious tasks. Artificial intelligence and the digitalization of health care will empower physicians to work more efficiently, create more accurate reports, and drive more impactful care to our patients. Evidence driven accelerated scan protocols more efficiently utilize the limited and expensive MR resources. Faster scanning enhances the patient experience and allows the delivery of care to more people. Innovations in the analysis and post-processing of image data can provide quantitative data not otherwise practical or detectable by qualitative methods.

MR Fingerprinting

The objectivity of MR Fingerprinting will facilitate the detection of subtle disease and the differentiation of pathologies. MR Fingerprinting is a quantitative approach to MR that allows simultaneous measurement of multiple tissue properties in a single, time-efficient acquisition. This back-to-the-future maturation of the Damadian vision to inform diagnosis via maps of tissue relaxometry [4, 5] now enables more objective diagnoses, inter-scan comparisons facilitating longitudinal follow-up of individuals, and development of imaging biomarkers [6, 7]. The fast, highly sensitive and reproducible parametric maps hold promise to differentiate various pathologies particularly in oncology. Additionally, the capacity to differentiate the borderlands of the normal and near-pathologic tissue has frequently been the discriminator of the novice and expert. Quantitation via MRF can elevate the objectivity of diagnosis and shift observer performance ROC curves up and to the left. More accurate and timely diagnoses, preventative strategies, and interventions will shift care from the hospital to the home and reduce costs.

A state of health

Health disparities and access to health care is an ongoing challenge that requires conscious efforts from multiple approaches. The extent and magnitude of these disparities is linked to geography and availability of diagnostic equipment and the required personnel to operate advanced technology. Additionally, the capacity to understand remote communities and their specific problems requires insight to their experience. We need to be present. Borrowing from the realm of lean process improvement, we need to go to the Gemba, the real place where the action is. Digitalized interconnectivity transforms the "house call" to the "digital Gemba" and removes the limitations imposed

"The promise of today's breakthroughs is not just efficiency – it's unleashing value creation and capture in a time of mounting performance pressure. But this will require driving a fundamental shift in the nature of work."

Cathy Engelbert and John Hagel III
in *Fulfilling the Promise of AI Requires Rethinking the Nature of Work Itself*, Harvard Business Review, 2017.

by distance. We envision a "state of health" in Michigan inspired by the land grant mission of our university that created Michigan Agricultural Experiment Stations in each of our 83 counties. Founded in 1888, these stations, now named the AgBioResearch Network, have played a pivotal role in enhancing agriculture, managing natural and community resources, and enhancing the quality of life in Michigan, the nation and the world. Similarly, the remote delivery of health care across our geographically dispersed but clinically integrated network throughout the state is connected through various telehealth solutions. Virtual Cockpit is one such digitally operationalized solution which will connect subspecialized and personalized care to the remote and underserved populations of the state. These advanced technology initiatives will extend the reach of our physicians. AI and technology can also facilitate the establishment and dissemination of best practices across geographies and is scalable beyond the state boundaries. Virtual Cockpit enables the system-wide dissemination and synchronization of protocols to take advantage of the latest technology. The remote operation and management of imaging equipment ensures the same level of service at all of our sites, extending our care to all the populations we serve, without geographical barriers or limitations. The Virtual Cockpit allows the implementation of standardized work. It enables generalist technologists and physicians to achieve optimal results, and the leverage of super-users for the remote performance of subspecialty imaging. As a community-based medical school with some campuses separated by more than 400 miles but connected by fiber, this enabling technology supports our core educational mission. This will unite the primary to the quaternary to deliver the best standard of care to all.

Connections

The connection to people and purpose has reciprocal benefits to patients and providers, staving off the ravages of burn-out on our physicians. Impossibility and despair are replaced by answers, solutions, and hope. Johann Wolfgang von Goethe's aphorisms often ponder what is possible. "A man must cling to the belief that the incomprehensible is comprehensible; otherwise he would not try to fathom it." [8] We are in a transformative era where innovation is refueling our inspiration, where the real limits are less technical and more of the imagination.

Pathway companions influence behaviors to add value

Ezekiel Emanuel points out that "the most pressing problem with the US health care system is not a lack of data or analytics but changing the behavior of millions of patients and clinicians." [9] This is where the simplicity and elegance of evidence-based clinical care pathways empower changes in clinician and patient behavior. The dealer's choice, often seemingly random ordering of tests that are not acted upon or create false positives requiring expensive follow up are eliminated by adherence to pathways. Evidence-based medicine is not new and associated appropriate practices frequently do not reach the patient. Technology solutions are emerging that are making encouraging in-roads toward successful creation and adoption of care pathways informed by AI that are integrated and "assimilated" into medical practice such that resistance is futile, or at least such that appropriate care is the easier path. AI informed care pathways and distributed innovation are impacting the entire value chain of medicine. The gains we enjoy are leading to operational optimization and facilitation of patient flow through our devices and care systems, while enabling the rapid diagnosis and personalized treatment of illness and the maintenance of health. Influencing the behavior of clinicians begins in their formation. As new generations of physicians emerge to take the helm of patient care and leadership of our profession, the judicious assimilation of AI-informed care will be organically accepted.

We want it all

The proposition that MR sequences should stop when the data sufficient for diagnosis is acquired rather than when the image is subjectively pretty is difficult to sell. This determination could be based on big data analytics and outcomes, and could be quantitative. The resulting image may not necessarily satisfy the current aesthetic, but instead answer the question regarding diagnosis or indicate the next patient management steps. This has proven to be a difficult sell to the visually motivated imaging professionals. Since the arrival of 3T, acceptance of faster rather than more beautiful images have been elusive. Micron level spatial resolution may have import for select applications, but most stroke, large vessel occlusions, disc herniations, and ligament or meniscal tears do not require more resolution than obtained at lower fields. The underlying paradigm shift required is the view of imaging as data, not portraits suitable for framing. Curating this data is the goal, and success will be beautiful in a different sense. But this too will require a shift in our thinking and behavior.

Conclusions

Magnetic resonance has its foundation in the spirit of curiosity and scientific inquiry and will continue to stimulate a passion for innovation for generations. It is integrated into patient care and provides critical insights on structure

and function in health and disease. The manifest transformation of health care with and through radiology will be through earlier and preemptive diagnosis, intervention, and surveillance of patients and populations. Cost-effective health management demands health maintenance. Imaging of established, macroscopic disease must become an aberration not the norm. This will allow diversion of precious resources toward the advancing the public health needs of our communities and the vexing problems of health disparities, poverty, substance abuse, maternal mortality, and mental illness. There are underserved populations and communities that we could not serve if it was not for this technology. The scope and scale of the Siemens Healthineers imaging community, with its robust clinical and research network provides a venue for the fruitful exchange of ideas, addressing both problems and solutions. Enjoy this showcase of the latest innovation and translational science advancing the care we provide in the pages that follow.

Mark C. DeLano

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